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United States Department of the Interior
National Park Service

NATIONAL REGISTER OF HISTORIC PLACES
MULTIPLE PROPERTY DOCUMENTATION FORM

This form is is used for documenting multiple property groups relating to one or several historic constexts. See instructions in How to Complet the Multiple Property Documentation Form (National Register Bulletin 16B). Complete each tem by entering the requested information. For additional space, use continuation sheets (NPS Form 10-900a). Use a typewriter, word processor, or computer, to complete all items.

X New Submission ___ Amended Submission

A. Name of Multiple Property Listing

Historic Highway Bridges of California

B. Associated Historic Contexts

(Name each asociated historic context identifying theme, geopgraphical area, and chronological period for each.)

The Evolution of California's Highway Bridges, 1855-1936

C. Form Prepared by

NAME/TITLE Donald S. Napoli
ORGANIZATION Napa Landmarks, Inc. DATE March 31, 2003
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CITY OR TOWN Sacramento STATE California ZIP CODE 95816

D. Certification

As the designated authority under the National Historic Preservation Act of 1986, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation. (___ See continuation sheet for additional comments.)

Stephen D. Mikesell 6/15/04
SIGNATURE OF CERTIFYING OFFICIAL DATE

CALIFORNIA OFFICE OF HISTORIC PRESERVATION
STATE OR FEDERAL AGENCY AND BUREAU

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

8/5/04
SIGNATURE OF THE KEEPER DATE

Table of Contents for Written Narrative

Provide the following information on continuation sheets. Cite the letter and the title before each section of the narrative. Assign page numbers according to the instructions for continuation sheets in How to Complete the Multiple Property Documentation Form (National Register Bulletin 16B). Fill in page numbers for each section in the space below.

Foreword

This multiple property submission is based on the information found in two thematic requests for determination of eligibility prepared by the California Department of Transportation in 1985 and 1986. The first examined truss bridges and the second all other types of bridges. The submission takes most of Sections E, H, and I directly from these two documents. Citations in parentheses, with T for the study of truss bridges and O for other bridges, appear at the ends of paragraphs reproduced with little or no editing. Some of the information upon which the requests were based is now out of date. In particular, specific bridges mentioned in the requests may no longer exist. For that reason the text has been edited to remove the implication that bridges singled out in the requests are still extant.

The requests led to determinations of eligibility for 72 truss bridges and 118 other bridges. The first set of determinations was made by the Keeper of the National Register and the second through a consensus of the State Historic Preservation Officer and the Federal Highway Administration. Determining bridges eligible for the register, however, has not proved entirely effective in preserving them. As many as 20 or 30 percent may have been removed or substantially altered in recent years.

It is not the intent of this submission to present new data or modify conclusions about historic highway bridges in California. Even so, a small amount of information from research completed after 1986 has been added. Otherwise, the submission attempts merely to arrange information from the eligibility studies in a manner to allow for abbreviated nominations to the National Register. The hope is that nominating bridges previously determined eligible will create more public interest in their preservation.

E. STATEMENT OF HISTORIC CONTEXT

1. Introduction

Nearly all the information in this statement comes from studies of truss and other bridge types completed in 1985 and 1986. The period of significance extends from 1855, approximate year of the first publicly built bridges in California, to 1936, fifty years before the end of the study. By 1936 the most important bridge types from the late nineteenth and early twentieth centuries were no longer playing important roles in the evolution of bridge building in the state. Truss and stone masonry bridges were no longer being routinely constructed, and concrete arch and concrete girder bridges seldom were seldom the subjects of innovation in design or construction technique.

2. Bridge-Building Institutions

Until the 1880s, highway bridge building in California was a predominantly private operation. While a few counties built public bridges as early as 1855, it was not until 1874 that the State Legislature adopted a comprehensive program through which counties could establish road districts, road commissioners, and property taxes earmarked for road construction.[1] The ability of counties to execute bridge construction was enhanced by an 1893 state law mandating each county to seek the advice of its county surveyor on bridge design. This law had the effect of professionalizing the office of county surveyor and helped attract trained bridge engineers to the office.[2] The situation was also improved by the 1907 passage of the Savage Act, permitting counties to incur bonded indebtedness to finance road and bridge construction.[3] Underlying this spate of activity was the appearance of large numbers of automobiles on county roads and the general "Good Roads" Movement, which gained statewide exposure with the State Road Convention of 1893.[4] (O: 22-23)

Between 1889 and 1910, county surveyors and other local officials designed or authorized hundreds of highway bridges. The bridges they built in many cases reflect local traditions and the preferences of the county surveyor. Stanislaus County, for example, built truss bridges for all types of crossings long after this bridge type had fallen out of favor in other areas. Napa County, with a long tradition of stone masonry in building construction, continued to build masonry arches until World War I. (O: 23)

More typically, counties built trusses early in this period but shifted gradually to reinforced concrete. The experience of Santa Clara County is instructive in this regard. John G. McMillan, county surveyor between 1890 and 1914, preserved what appears to be a complete set of plans for bridges he designed. McMillan was a railroad surveyor in California and Central America, a mining engineer, and an engineer for Stanford University before his election as Santa Clara County Surveyor. His earliest bridges were "combination" (timber and steel) trusses or wooden trestles. In 1896, he began to build concrete bridges. He experimented with various unorthodox reinforcing systems, combining concrete and stone in an 1896 bridge, concrete and brick in another, and concrete with a steel arch truss in 1897. He was also quite sensitive to design considerations for bridges in pastoral rural areas, often working native rubble into the texture to create a "harmony" with the natural environment. Two such structures—37-74 and 37C-237—were determined eligible for the National Register in 1986. Although his bridges were often eccentric, McMillan's transition from truss to concrete bridge design was typical of surveyors throughout the state.[5] (O: 23)

For all counties, the transition from metal truss to concrete bridge design included a certain amount of experimentation. San Mateo County, for example, decided in the late 1890s to built a number of short span concrete arches across small streams that traverse the area. The county surveyor, apparently unfamiliar with the principles of concrete construction, contracted with the San Francisco consulting engineering firm of D. Bromfield and C. Tobey to design these structures. The contract for one such structure was let in 1899. It was canceled, however, when the contractor declared that "the specifications were defective to such an extent that structure if built thereto would be utterly worthless."[6] Perhaps because of such problems, the county surveyor installed a bronze marker on the first concrete arch to be completed, bearing the inscription "First Concrete Bridge Erected in San Mateo Co. 1900." This structure, 35C-25, was built to span Pilarcitas Creek on Main Street in Half Moon Bay. (O: 23-24)

By 1910, most local governments, cities as well as counties, had gained the expertise to design concrete bridges on their own. The leaders in this regard were the city and county of Los Angeles. Arguably the first American city to experience persistent traffic jams, Los Angeles officials recognized early the need for improved arterial streets and viaducts to carry traffic across the Los Angeles River and adjacent railroad tracks. Prototype viaducts were built in 1910, including the massive Buena Vista (North Broadway) Bridge (53C-545), probably the original open spandrel arch bridge in California, and the smaller Main Street Bridge (53C-1010). The Buena Vista Bridge was a prototype, not only for traffic planning and use of the open spandrel form, but for Beaux Arts detail and monumentality as well. City officials noted with pride that this structure was designed entirely by civil servant engineers. (O: 24)

The great engine for bridge construction was not local highways, for massive local programs such as that in Los Angeles were rare. Instead, the major impetus for highway bridge construction and innovation in bridge design, was the development of a state highway system. (O: 24)

The origins of the system trace back to the late nineteenth century. A statute enacted in the first session of the California legislature in 1850 empowered the state's Surveyor General to make suggestions for road improvements. Only one road—the Lake Tahoe Wagon Road—was built with state assistance before 1895. (O: 24)

In 1895, the State Legislature created the Bureau of Highways to study routes for potential state highways. Two years later, this agency was renamed the Department of Highways and given minor appropriations for acquisition of land and road improvements. In 1907, this department was incorporated into the larger Department of Engineering, along with water development, architectural services, and other public works agencies. In 1910, California voters approved the first of several multimillion dollar bond measures to finance large-scale highway construction. The 1911 Chandler Act passed by the State Legislature created an advisory board, the California Highway Commission, forerunner of today's California Transportation Commission to establish policy and oversee expenditure of bond act money.[7] (O: 24)

The building of State highways at different time and in different counties called into service the work of county engineers, private consulting engineers, and the staff of the state highway department. In its first policy statement on bridge construction in 1912, the California Highway Commission requested that counties supply bridges that could connect with State-constructed roadways,[8] shifting the major burden for state highway bridge construction to the local level. Only rarely did the Highway Commission staff design bridges during the first two decades of the century. The oldest bridges designed by the state and extant in 1986 date from the mid-teens—10C-143, built in 1913, and 36C-48 and 6-195Y, both built in 1915. (O: 24-25)

The building of U.S. 101 in Santa Barbara County illustrates how state highway construction influenced both local public officials and private consultants. This route was one of the earliest major north-south State highways, and nearly 100 miles of this route pass through Santa Barbara County. It crosses numerous deep ravines and arroyos; today, there are more than 100 bridges along U.S. 101 in Santa Barbara County. (O: 25)

The county spent hundreds of thousands of local tax dollars designing and building bridges for this route between 1910 and 1920. Designing these many structures taxed the abilities of county surveyors F. Flournoy and O. H. O'Neill. Neither was trained in bridge design and both pleaded with the county to provide them with more assistants to handle this task.[9] Unable to secure sufficient in-house expertise, they turned to consulting engineers in Los Angeles to design state highway structures. Offering a royalty of two and one-half percent of construction costs, Flournoy and O'Neill attracted the services of the better consulting firms—Mayberry and Parker, Thomas and Post, and Edward T. Flaherty. In several instances, two or more firms submitted proposals for a single structure, enabling the Board of Supervisors to seek bids on multiple alternatives. (O: 25)

Even with these consulting services, the County was unable to keep up with highway construction. In 1917, the Board of Supervisors requested that the California Highway Commission prepare plans for a major structure across the Arroyo Hondo. This bridge afforded the small state Bridge Department staff its first opportunity to design a major span. The resulting structure, 51-27Y, previously determined eligible for listing in the National Register, was a structural and aesthetic success; in the 1980s it was bypassed and preserved in place. (O: 25)

It is not surprising that the Arroyo Hondo was a reinforced concrete arch, for the Highway Commission showed a preference for concrete bridges from the outset. In a 1912 policy statement pertaining to bridge design, the Commission declared itself "in favor of concrete structures whenever such structures are consistently possible because of their substantial permanency."[10] (O: 25)

In addition to encouraging local agencies to design concrete structures, the Commission practiced this policy as well. In a 1920 study of the operations of the California Highway Commission, the U. S. Bureau of Public Roads identified 47 bridges designed by Commission staff. Of these, 39, or 82 percent, were of reinforced concrete.[11] The majority were smallspan concrete girder bridges. Large spans were concrete arches. (O: 25)

By 1923, the California Highway Commission had grown weary of waiting for counties to complete structures. Assured of a predictable source of funding with the 1923 passage of a 2 cent per gallon gas tax, State Engineer, R.M. Morton "directed that the construction of all bridges, as well as their design, should, in the future be under the direction of the Headquarters Bridge Department."[12] This directive shows the growing confidence the Commission placed in the design staff assembled by Bridge Engineer Harlan D. Miller. In 1924, Miller's staff included two office engineers, four designers, twelve draftsmen, ten construction engineers, one cost estimator, and one specifications writer.[13] (O: 26)

After 1924, virtually all state bridges were designed by state engineers. A corresponding professionalization occurred at the local level. The role of the consulting bridge engineer was restricted to design of specialty structures, such as movable bridges, or very large structures, such as the Golden Gate Bridge. Financial arrangements were similarly well-established by the 1920s, with the state assuming responsibility for funding bridges on state highways and local governments funding strictly local structures, and with the Bureau of Public Roads (now Federal Highway Administration), supplying federal aid at both levels. Special arrangements were required, however, for special circumstances—for very large and expensive structures, such as the Golden Gate Bridge, for bridges on federal lands, for bridges crossing county lines, and for bridges associated with federal flood control projects or with the various New Deal works projects, such as the Civilian Conservation Corps or Works Progress Administration. (O: 26)

Several conclusions may be drawn from the foregoing. First, the bulk of California highway bridges were designed by civil servants, either county surveyors or engineers in the Division of Highways (Caltrans). Some of the more interesting bridges, however, are those designed by consulting engineers in the early part of the century, when expertise was wanting in the civil service. These consultant-designed bridges are often the most innovative and are highly represented in the group of bridges determined eligible for the National Register in 1986. Second, the typical bridge built in California between 1900 and 1935 was of reinforced concrete, with girders serving shorter spans and arches serving the larger spans. Suspension bridges, while constructed on occasion in the nineteenth century and in greater numbers in the 1930s, have never accounted for more than a tiny fraction of California bridges. Stone masonry bridges are predominantly a nineteenth-century type, built later only in selected regions of the state. Steel arches and steel girders have been utilized sparingly as highway bridges in California, chiefly since the 1930s. (O: 26)

3. Truss Bridges

Admitted to the Union in 1850, California developed and matured along with the American truss building industry. One finds on California highways examples of all phases of truss bridge design, from the pioneering truss types of the 1840s, to the bold long-span cantilevers of the 1920s, to the movable truss spans of the early- to mid-twentieth century. The history of California trusses is an intertwining of three threads—the technological history of truss design, the political and administrative history of public road building agencies in California, and the economic and social development of California into the most populous state in the Union. (T: 15)

In California as elsewhere, the nineteenth-century truss bridge was chiefly a railroad bridge. California counties built few bridges before 1880,[14] and it was not until the automobile age of the early twentieth century that substantial numbers of highway bridges were constructed by public agencies. Not surprisingly, such highway truss bridges as exist from the nineteenth century are essentially railroad-type structures. (T: 15)

The group of bridges determined eligible for the National Register in 1985 includes fourteen nineteenth-century trusses. These, along with ten others already listed in or determined eligible for listing in the National Register, give a picture of the types of trusses constructed during this period. They can be classified in three basic groups: covered bridges, most originally built as toll road bridges; metal railroad trusses converted to highway use; and metal trusses originally built by counties for highway use. These structures are clustered in remote areas of the Coast Range mountains or in the foothills of the Sierra Nevada. (T: 15-16)

Covered bridges in California and elsewhere primarily employed wood trusses. Occasionally they used some metal elements. Wood truss bridges date to the Middle Ages. Their modern form, however, which multiplied the basic truss pattern to enable long spans, did not arrive until around 1800. The bridges were fairly easy to construct, but their longevity was limited because the timbers were open to water and wind damage. So American bridge builders began adding protective roofs and walls to wood trusses. Most of the engineers who designed innovative truss bridges also built covered bridges. This group includes Timothy Palmer, Theodore Burr, Lewis Wenwag, Ithiel Town, Stephen Long, William Howe, and Thomas and Caleb Pratt. By the time of the Gold Rush, hundreds of covered bridges had been constructed in the eastern United States. The most common forms were the Howe, Warren, and Burr

Arch trusses. A familiar variation combined truss and arch. Wood truss bridges, both covered and uncovered, enjoyed only a brief period of popularity in California. They soon gave way to metal trusses, which were stronger and more resistant to the elements. Their removal and replacement continued well into the twentieth century. Only eight nineteenth-century covered bridges remain today. Because they are unusual and picturesque, all are subject to serious preservation efforts.[15]

The majority of nineteenth-century metal trusses were built by California-based bridge building companies. California supported more than a dozen such companies, although these "bridge companies" appear to have been much less specialized than their eastern counterparts. Virtually all known California bridge builders were diversified metal fabricators, in most cases specializing in products other than bridges. The Dyer Brothers-Golden West Iron Works, for example, specialized in bank vaults and metal roofing material but built bridges as well.[16] The San Francisco Bridge Company, despite its name, was chiefly involved in fabricating mining equipment.[17] The Dundon Bridge Company, with one bridge in this inventory, was also involved in manufacturing brewery equipment.[18] The Judson Manufacturing company was heavily involved in making agricultural implements. The Pacific Bridge Company and its successor, the Pacific Construction Company, was involved in major building construction, including the San Francisco Ferry Building.[19] The Thomson Bridge Company was best known for its harbor work.[20] (T: 16)

Perhaps because bridge building was often a sideline for these firms, nineteenth-century trusses by California manufacturers tend to be quite conservative, using popular truss types developed elsewhere. In bridges as in architecture[21] it would be well into the twentieth century before California designers would develop a distinctive regional "style." (T: 16)

Three powerful forces combined around 1900 to change the design and construction of truss bridges in California. First, the organization of the American Bridge Company as a subsidiary of U.S. Steel created a national firm capable of overcoming the natural advantages enjoyed by California-based builders. American Bridge at the time of its organization controlled 50 percent of America's bridge fabricating capacity[22] and would soon dominate truss fabrication throughout the United States. Of the extant trusses in California for which the builder is known, American Bridge was responsible for 25 percent of those built between 1900 and 1910, 37 percent of those built between 1911 and 1920, and 45 percent of those built in the 1920s. By the 1930s, this percentage began to diminish, likely because the number of truss bridges was so small that national competition was not economical. (T: 16)

In a second development, after 1900 county surveyors, and later state bridge designers, played more active roles in bridge design. Where nineteenth-century trusses were commonly designed as well as built by bridge companies, twentieth century bridges were almost always designed by public officials or private consultants for public officials. (T: 16-17)

Third, after 1900 the truss fell into disfavor among county, city and state bridge designers for use in cities or sensitive rural areas. The truss was anathema to City Beautiful advocates like Charles Mulford Robinson, who in 1909 advised the City of Los Angeles that existing trusses were "about as ugly as they can be. As these are replaced, handsome structures should be substituted."[23] This "handsome" bridge was almost always a reinforced concrete arch. Even in rural Santa Clara County, the county surveyor recommended the concrete arch over the truss because it could be made "in harmony with the locality."[24] (T: 17)

These three developments, coupled with a large increase in the number of bridges being built, changed the role of the truss bridge. The typical truss after 1900 was designed by a county surveyor to standard American Bridge Company specifications, and was located across a major crossing in a remote area. Further, the truss occupied a decreasing proportion of the total number of bridges being built. By the 1930s, the truss was used very rarely for "ordinary" spans—fixed bridges of small to moderate length. (T: 17)

Metal trusses continued to be used, however, for extraordinary situations, and a large proportion of trusses determined eligible for the National Register in 1985 are of an extraordinary character. Examples of such special-purpose trusses are swing bridges, bascules, and longspan cantilevers. Trusses of this sort are exceptional in their engineering achievements and in their contribution to transportation history; they span crossings that call for extraordinary engineering solutions. (T: 17) Swing bridges were the most popular type of movable bridge in California after 1920.[25]

Four swing bridges, built between 1906 and 1931, were determined eligible in 1985. All are located along the shipping channels of San Joaquin and Sacramento County and played key roles in providing concurrent land and water transportation in this topographically difficult area. (T: 17)

Six bascule bridges were determined eligible in 1985. Like swing bridges, bascules are significant for their technological complexity and for their role in facilitating concurrent land and water transportation in key areas of the state. Two are located in the port area of San

Francisco, three along shipping channels in Sacramento County, and one in the harbor area of Los Angeles. While ranging in date from 1916 to 1933, all were designed by Joseph Strauss, the internationally recognized bridge designer who resided in California after 1921. (T: 17) One, the Third Street Bridge in San Francisco (34C-25), was acclaimed as the world's largest bascule bridge when it was constructed in 1933.[26]

Now missing from California's collection of special-purpose truss bridges are two that once crossed San Francisco Bay. The first, the 1927 Dumbarton Bridge, had at its center nine truss spans, of which one was a vertical lift. When completed, the bridge was the longest in the world. That distinction lasted only two years, however. In 1929 the even longer San Mateo-Hayward Bridge was constructed about eight miles to the north. The new bridge also had central truss spans, one of which was a vertical lift. Both bridges were later replaced.[27]

Finally, the 1927 cantilever span across the Carquinez Straits and the 1937 San Francisco-Oakland Bay Bridge are highly significant in both engineering and transportation history. As the first major span across an arm of the San Francisco bay system, the Carquinez Straits Bridge was recognized in 1927 by Dean Charles Delreth of the University of California School of Engineering as "the beginning of an era of local bridge building and traffic expansion around San Francisco. The Carquinez bridge will make our people realize what it means to link metropolitan communities by great bridges."[28] The bridge was also accorded international recognition for reviving the long-span cantilever bridge form, which had fallen into disfavor fifteen years earlier with the collapse of the Quebec bridge and major redesign of the Queensborough cantilever span.[29] With twin spans of 1100 feet, the Carquinez bridge was surpassed in length only by the Queensborough bridge the second Quebec cantilever, and the Firth of Forth bridge.[30] (T: 17-18)

Dean Delreth's comments regarding the effect of completion of the Carquinez Bridge were prophetic, for during the 1930s Californians were preoccupied with the task of spanning San Francisco Bay. The crowning achievements of this effort were the Golden Gate Bridge and the San Francisco-Oakland Bay Bridge. Each is a truss in some respects, in that the deck of the Golden Gate suspension spans are stiffened by trusses. Only the Bay Bridge eastern spans were treated as trusses in the 1985 survey. And great trusses they are—52 spans for a total length of 11,327 feet, with a central cantilever span of 1400 feet. Superlatives of every sort apply to this structure—longest high bridge in the world, most expensive bridge ever built at the time, among the largest truss spans in the world.[31] (T: 18)

In addition to specialized uses, California engineers also experimented with specialized truss designs. Two small spans in the San Joaquin Valley (38C-168 and 42C-551), built in the 1910s and extant in 1985, combined the truss form with reinforced concrete materials. Four Vierendeel trusses designed by the Los Angeles District of the Corps of Engineers were the first Vierendeels built in the United States and the only such trusses in California. In 1985 they may have been the only extant Vierendeels in the United States.[32] The Maple Canyon bridge in San Diego, designed in 1931 by John C. Shaw, formerly City Engineer in Los Angeles, did not have a new form but was an unusually decorative truss and an unusually successful attempt to make the truss conform with 1930s standards for a beautiful urban bridge. (T: 18)

One of California's leading builders of truss bridges in the 1920s and 1930s was the Moore Dry Dock Company of Oakland. Like earlier bridge-building firms, the company fabricated steel for other purposes. Ship-building was a specialty. The Moore Company put up truss bridges in the Bay Area and throughout northern California. It also provided some of the steel for the Golden Gate and Bay Bridges, which are discussed in Section 6 below.[33]

4. Reinforced Concrete Arch, Girder, and Slab Bridges

Reinforced concrete—concrete with embedded steel bars which bond with the concrete and provide tensile strength—was first used as a building material in Europe in the late 1840s. Use of this building material in the United States dates to the mid-1870s. Early reinforced concrete structures built in the United States were large residences, warehouses, and sidewalks.[34] (O: 26-27)

Europeans were first to utilize reinforced concrete in bridge construction, building several arched bridges in the mid-1880s, using the "Melan System," which relied upon steel I-beam reinforcement, and the "Monier System," which used wire mesh reinforcement. The first American reinforced concrete bridge was an 1889 arch built in San Francisco, which used the twisted reinforcement bar developed by Californian E. L. Ransome.[35] (O: 27)

After 1900, European and American engineers went in separate directions in reinforced concrete bridge design. Where European bridges tended toward the thin, elegant and non-historical designs of Robert Maillart, Eugene Freyssinet, and others,[36] American reinforced concrete bridges used bulkier arches decorated with historical detail.[37] Maillart pointed the way for a distinctively European reinforced concrete bridge, while the early designs of George Morison may be seen as typifying the American approach. (O: 27)

California reinforced concrete bridges are both typical and exceptional within the larger context of American structures of this type. Certainly they are as a group much closer to Morison's designs that to Maillart's. (O: 27)

What is distinctive about the California concrete bridges is that they are numerous and "home-grown." Owing to the high cost of steel on the West Coast and the ready availability of high quality cement in California, concrete construction was economically feasible earlier in California than elsewhere. In absolute numbers and in proportion to the total number of historic bridges, reinforced concrete structures appear to be more numerous in California than in any other state in the union.[38] (O: 27)

The vast majority of California reinforced concrete bridges were designed by Californians. A few were the work of well-known out-of-state engineers: J. A. L. Waddell designed the Colorado Street Bridge in Pasadena and Bertram Goodhue helped design the Cabrillo Bridge in San Diego; both bridges are listed in the National Register. D. B. Luten designed the Orland Bridge (11C-196). Most California concrete bridges, however, were designed by engineers in the employ of California local government, state government, or by private consultants with offices in California. (O: 27)

These Californians left a distinctively regional imprint on the body of California concrete bridges. This imprint was often technological. California engineers were innovative and quick to patent their discoveries. Equally important, California engineers developed a comprehensive design aesthetic for bridges that could to conform to the desirable urban, rural, and wilderness environments in the state. (O: 27)

Pioneering work by Californians in reinforced concrete design began in San Francisco in the late nineteenth century. It was chiefly concerned with commercial and industrial buildings and secondarily with transportation features, such as sidewalks, roads, and bridges. The driving force behind this early phase of reinforced concrete work was Ernest L. Ransome. (O: 28)

Ransome arrived in San Francisco during the 1860s, fresh from apprenticeship in his father's iron-works factory in Ipswich, England. In San Francisco he supervised the Pacific Stone

Company, which manufactured and marketed concrete blocks according to his father's patent. In the mid-1880s, Ransome began devising a number of innovative techniques in the use of plain and reinforce concrete, nearly all of which he patented. His patents included an 1882 expansion joint for concrete sidewalks, an 1884 twisted reinforcement bar, an 1884 concrete mixer, and an 1888 mold for pouring concrete tunnels.[39] Ransome also had a number of major commissions for buildings in Northern California, most in conjunction with architect George Percy. (O: 28)

In 1888-9, Ransome, probably in conjunction with Percy, designed the Lake Alvord Bridge in San Francisco's Golden Gate Park. The bridge was designed to carry a carriage road across a pedestrian pathway connecting the Haight Street entrance to the park to a newly constructed Children's Playground. The bridge is remarkably unmodified and still in use. This, the first reinforced concrete bridge in the United States, passed almost without notice at the time it was built. The Board of Park Commissioners noted in their 1889 report that "Over the walk a very handsome bridge has been erected and the drive graded up to the crown." Ransome himself did not even mention the structure in his lengthy 1912 reminiscences on his early work in San Francisco. Apparently no plans exist today for this bridge so we cannot say with certainty how it was built. It is highly likely, however, that Ransome used his own patented twisted bar for reinforcement, as he did with most major commissions after 1884. (O: 28)

The Lake Alvord Bridge is highly significant in two regards. First, as noted it is the oldest reinforced concrete bridge in the United States, predating by four years the first "Melan-system bridge" built in the United States. Second, in his use of twisted bar reinforcement, Ransome pointed the way to the predominant twentieth century practice. The alternative system, developed by Joseph Melan and introduced in the United States by Fritz von Emperger, utilized heavy I-beam reinforcement. Interestingly, Ransome himself initially utilized I-beam reinforcement but developed the twisted bar because I-beams were expensive and, being smooth, would not bond adequately with the concrete.[40] While relatively few plans remain for reinforced concrete bridges built in California before 1905, it seems clear that California engineers did not adopt the Melan-system, popular elsewhere in the United States, but rather began and continued with the superior Ransome system of reinforcement. (O: 28)

The most likely forum for spreading word of Mr. Ransome's ideas about concrete bridge reinforcement was the Technical Society of the Pacific Coast, an eclectic organization for engineers, construction contractors, and other professionals in the San Francisco area.[41]

Ransome was an active member of this organization, as were many of the other Northern California engineers who experimented in reinforced concrete bridge construction before 1910. (O: 29)

One engineer who was a member of the Technical Society and at the forefront of early reinforced concrete bridge design was John Buck Leonard. Leonard, born and educated in the Great Lakes area, came to California in the 1880s. For nearly two decades he worked for bridge building firms, including the Southern Pacific Railroad and Healy-Tibbetts & Co. In 1904, he set up his own office in San Francisco, specializing in concrete bridges and, to a lesser degree, in reinforced concrete buildings. His first bridge was a closed spandrel reinforced concrete arch across the Truckee River in Reno, Nevada, still standing. He continued designing closed spandrel arches of surprisingly large spans through 1911. The greatest of these was the 1911 Fernbridge on the state highway across the Eel River in Humboldt County. This massive structure includes seven 200 foot spans, to this day the largest closed spandrel concrete arch bridge in California (4-134). From the 1910s through the early 1920s, Leonard experimented with a "canticrete" system of reinforcement. Similar in some respects to the Melan system, a "canticrete" structure utilized a cantilevered truss of steel I-beams to provide a sidewall and floor substructure. The truss was designed to cut costs in form work. The greatest of these was the Seventh Street Bridge in Modesto, California (38C-42). A smaller canticrete bridges was the Larkin Street Bridge (44C-82) in Monterey. Late in his career, Leonard designed a number of very elegant open-spandrel arch structures using more conventional reinforcement systems. One example of this late period was the Chili Bar Bridge (25-33) on the American River.[42] (O: 29)

After about 1910, several important consulting bridge design firms operated from Los Angeles offices. One firm, Thomas and Post, was founded by William Thomas, one of the most creative of the early reinforced concrete bridge designers in California. Born in St. Louis, Missouri in 1876, Thomas studied architecture at the Chicago Art Institute. After working as a structural engineer on railroad terminals, Thomas moved laterally into railroad bridge engineering. By 1906, Thomas had moved to California to work with the Union Traction Company, an interurban line in Santa Cruz, California. (O: 29)

It was in the employ of this firm in 1906 that he devised the bridge that would thereafter be known as the Thomas System, or the Thomas Three-Hinge Arch. Thomas did not invent the three hinge arch, an arch with hinges at each abutment and the crown; hinged arches had precedent in metal bridges and had been executed in concrete in Europe before 1906.

Thomas was aware of European precedents—in a 1914 article, he listed twelve German bridges he studied before building his Santa Cruz structure. Thomas' innovation was to precast arch rings in molds on the ground, hoist these into place and fix them at the hinges. In time, Thomas, who set up a private practice in Los Angeles shortly after completing the Santa Cruz bridge, built dozens of such structures in California, chiefly in the Southern counties. Unfortunately, very few remain. The original Santa Cruz bridge remains but has been altered considerably. (O: 29-30)

The most impressive of the Thomas System structures remaining in 1986 was the Parks Bar Bridge on State Route 20 (16-11). Later demolished, it was by far the longest of the then extant Thomas arches and, at 685 feet total length, with a main span of 140 feet, was an impressive early concrete arch of any configuration. The bridge also typified Thomas' approach to bridge aesthetics. Although he published many articles on bridge engineering, Thomas, a trained architect, was entirely silent on the issue of bridge architecture. We can infer his aesthetic principles, however, from his *oeuvre,* with the Parks Bar Bridge being the best example. Thomas eschewed applied decorative features altogether. The beauty of his bridges is in the clean lines of the parabolic arches and in the straightforward lines of the piers and abutments. Even his railings were unadorned; Thomas designed only simple pipe railings, such as those found at Parks Bar. While he may be seen as simply overlooking architectural detail for his overriding interest in engineering innovation, a more likely explanation is that he saw a beauty in the lines of the bridge and intentionally eliminated applied decoration. To this extent, he was as forward looking in bridge architecture as he was in bridge engineering, anticipating the aesthetic approach utilized by the California Division of Highways in its famous arches of the 1930s. The Parks Bar was, in a phrase used by Thomas to describe a near-twin in Ventura County, "a pleasing structure, obviously strong and permanent."[43] Other Thomas Three-Hinge Arch bridges extant in 1986 were 51C-39 and 57C-361. (O: 30)

The Thomas System is important, not simply because it was three-hinged but for its use of precast concrete bridge members. Thomas also patented a reinforced concrete slab system, originally designed for warehouse used but adapted for bridge use. Only one example of this bridge type existed in 1986—41C-6, in Madera County. (O: 30)

Mayberry and Parker, another Los Angeles private consulting firm, designed many concrete arches in the first two decades of the twentieth century. Their contribution to the field, however, was primarily in the design of concrete girder structures. Similarly, Edward T. Flaherty, another Los Angeles-based bridge and structural engineer, designed some arch bridges but is best known as the engineer responsible for introducing the "Slab-Mushroom Column" system patented by C. A. P. Turner to California. In 1986 probably only two Turner System bridges remained in the state. One was designed by Flaherty using patented Turner reinforcement (29C-232), in Stockton. The other, 25C-116, employed a reinforced concrete arch, with the Turner mushroom-and-slab system used in the spandrel columns and deck. (O: 30-31)

In time, the momentum for bridge design passed from these consulting engineers to local and state civil servants. It is more difficult to assign individual responsibility for public structures, but certain individuals do stand out among the hundreds of individuals involved. (O: 31)

The California Highway Commission was from the outset staffed with talented bridge designers. Harlan D. Miller was the second state Bridge Engineer. Born and educated in Ohio, Miller, like many private bridge engineers of the period, began his career designing railroad structures. He later worked with a private engineering firm in San Francisco. In 1919, he joined the staff of the California Highway Commission, rising to chief of the bridge department in the early 1920s. It was Miller who directed that the department take over all state highway bridge design and construction and who presided over expansion in the department. Miller's lasting contribution was in the area of bridge architecture. He insisted that great attention be paid to those details that, in his view, defined a handsome structure—railings, endposts, spandrel detail, and so forth. This tradition would continue after his death in 1926 and indeed became something of a signature for state bridges, particularly long-span reinforced concrete arches. One of Miller's most successful bridges is the Donner Summit Bridge, 17C-152.[44] (O: 31)

Miller's successor, Charles E. Andrew, came to California after work with the Oregon State highway department and with nationally-known bridge designer, Ralph Modjeski. Andrew, along with State Highway Engineer, C. H. Purcell, had been involved with the design of the handsome concrete arch structures along Oregon's Columbia River Highway, and brought this design aesthetic to the California Highway system.[45] (O: 31)

In 1928, Andrew outlined the design principles that guided the operations of his departments. "It has been said," Andrew observed, "that no objects in America more greatly mar the landscape than the bridges, and none in Europe are more attractive." The general American failure he attributed to "lack of artistic training in engineers, limited resources, competition and haste in construction, undesirable or unsymmetrical location, inadequate materials, absence of state or municipal supervision." Andrew called for "higher ideals in bridge designing" and saw special opportunity for such structures along the scenic, remote reaches of the state highways. "It is the hope of the bridge engineer," he noted, "that the finished structure will be durable, pleasing in appearance, conform to the canyon or stream; so that both layman and engineer will gain the impression that bridge construction is being kept abreast with building of modern highways."[46] (O: 31)

The Division of Highways succeeded in answering Andrew's "higher ideals" with many of its wilderness bridges, but none succeeded so spectacularly as the series of early 1930s structures along State Route 1 between Carmel and San Luis Obispo, along the rugged and beautiful Big Sur coastline. Among these, the Bixby Arch (44-19) became the best known. Its fame as one of the most beautiful bridges in the United States owed in large part to the lightness of its form, especially the tapering parabolic arch ring which appear paper-thin at the crown. It is as well a pleasing complement to the rugged Big Sur coastline, expressing its own power and gracefulness but with a very slender profile. (O: 32)

Among municipal bridges, the viaducts across the Los Angeles River were especially noteworthy. These structures embodied precocious transportation planning, combining grade separations with a set of arterial streets linking the downtown areas with residential suburbs. Many were also technologically innovative, such as the 4th Street Bridge, which was reported in professional literature for its innovation in a "fixed-hinge" design, and the Glendale-Hyperion Bridge, which accommodated an extremely complex traffic flow. (O: 32)

The Los Angeles Viaducts were notably successful in addressing City Beautiful concerns for bridges as urban monuments. The case for the City Beautiful bridge was made forcefully in a 1913 article in *The Architect and Engineer of California* by H. G. Tyrrell. As a city grows, Tyrrell argued, bridges will proliferate at major crossings. These many bridges "will stand at almost every water crossing, either as an honor or as a shame to their originators." These bridges, in his view, should be treated as public monuments, like post offices or city halls, and decorated in the same manner. "The proper rule for the beautifying of public works is to adorn those structures which are of greatest public service." The adornment he had in mind was the Beaux Art classicism of the 1893 Chicago World's Fair. Given this sense of proper decorative, Tyrrell ruled out use of the truss, which he called an "abomination and should be avoided wherever possible," and recommended bridges that could be given decorative treatment, which in the technological vocabulary of 1913 meant the reinforced concrete arch.[47] (O: 32)

This same conception of the City Beautiful bridge was expressed earlier by Charles Mulford Robinson in his 1909 report, "The City Beautiful," to the Los Angeles Municipal Art Commission. He chided the city for erecting truss bridges as major river crossings, arguing they are "about as ugly as they can be. As these are replaced, handsome structures should be substituted . . . the concrete arch now makes practicable a bridge that is beautiful at no more cost than the old ugly iron bridge of the railroad type."[48] Very difficult and lengthy legal battles, taken even to the U.S. Supreme Court, delayed construction of these bridges for several decades. (O: 32-33)

Passage of a large bond measure in 1923 made construction of viaducts possible. As the city prepared for the design of these many structures, it clearly had not forgotten the advice of the original City Beautiful advocates. City Engineer, John Griffin, promised the city council that traffic circulation practicalities and architectural sensibilities would go together in design consideration. "The character of the structures will be such as to excite favorable comment from visitors who enter and leave Los Angeles by the railways, and their construction will not only relieve traffic congestion, but will raise the status of Los Angeles as an enterprising, properly developed city.[49] (O: 33)

When the viaducts were essentially completed in 1932, the city engineer took time to reiterate the intent of the program and point to his success in insuring that "the viaducts themselves have taken their place among the sightly structures of the city." (O: 33)

If one considers the total body of reinforced concrete bridges in California, from the stone-faced arches of J. G. McMillan to the great span wilderness bridges of the Division of Highways, to the ornamental urban monuments of Los Angeles, it is clear that Californians were particularly successful in adapting the reinforced concrete arch to a diversity of environments. They recognized the plasticity of concrete as a building material and the inherent beauty of the arch form, and developed different concrete arch designs for the varied environs of California. This may ultimately be the most important contribution of California bridge engineers to reinforced concrete bridge technology and to the cultural landscape of California. (O: 33)

5. Stone Masonry Bridges

The closed spandrel, earth-filled masonry arch bridge is one of the oldest types of man made structures used to cross rivers and valleys. Masonry arches were built as early as 3000 B.C.

in China, though the Romans are most renown for building numerous stone arch bridges which linked the Roman Empire with an extensive highway network.[50] (O: 33)

An early design feature of masonry bridge building from the Roman period was the use of a large stone arch ring with smaller material used in the spandrel walls. Generally, during this period arches built in Western Europe were either circular or elliptical shaped while in Eastern Europe and Asia the pointed (gothic) shape was often used. Although advanced in bridge engineering, the Romans constructed crude foundations. Commonly, loose stones were thrown in the river until a platform (pier) on which they could construct their masonry arches was achieved."[51] (O: 33)

Following the fall of the Roman Empire, masonry bridge building declined and was characterized by the construction of massive, crudely designed arches. However during the 16th to 17th centuries, bridge building began to exhibit greater refinement of design. This was due to improvements in foundation construction, increased use of wood pilings, and better skilled stone masons. (O: 33-34)

Following the 18th century iron, steel, and later concrete emerged as the preferred building materials for bridges. These materials allowed for the construction of other types of bridges; however, masonry bridge construction did continue with regularity to 1925. (O:34)

Europeans are recognized for bringing the art of stone arch bridge construction to the United States. However, it was quickly realized that the masonry arch bridge so common in Europe was not adaptable to many river crossings in the United States. Their short spans and massive piers were too narrow to allow ice flows to pass and subsequently trapped floating debris. (O:34)

Nevertheless, prior to about 1912, many masonry arches were constructed in this country wherever the right conditions existed. Some of these noteworthy bridges were: the High Bridge which served as a aqueduct in New York; the Cabin John Arch, built in 1864 in Washington D.C.; and the Memorial Bridge, built in 1912 to cross the Connecticut River.[52] (O:34)

California's earliest bridges were built using local materials and a minimum of labor. Labor was in short supply in the mountainous areas of California. Often truss and suspension bridges were used to cross rugged terrain. Occasionally, simple timber stringer bridges incorporated masonry work in piers, abutments, or wingwalls. Here stone from nearby fields or the streambed was utilized. (O:34)

California's stone masonry arch bridges are concentrated in Napa County. There the early depletion of the local timber, combined with numerous small creeks and a river that could be crossed with a short span or spans, set the stage for stone masonry bridge construction. (O:34)

The prevalence of stone construction in the Napa Valley can be linked to a number of factors. First, the early settlers of the Napa Valley were largely from the rural provinces of Europe. Among these immigrants were experienced stonemasons who brought the building methods and technologies of their native lands. Their farms and vineyards called for building of fences, bridges, distilleries and cellars, and for this they used the techniques with which they were familiar.[53] (O:34)

Second, appropriate natural resources were readily available. Native stone was first quarried in Napa Valley in 1846 for the burrs, or millstones, used in the Bale Mill. Napa Valley's rock-ribbed mountains are abundant with limestone, sandstone and volcanic tuff. These stones presented cheap, available building material that could be handled rapidly for the construction of buildings and bridges. As many as thirteen quarries were located in the valley. Suitable building stone was also available in nearby fields and stream beds. (O: 34-35)

Third, indentured Chinese who came to work in the valley's vineyards and quicksilver mines provided abundant and inexpensive manual labor. Since the mines ceased effective production within a very few years, and since extensive labor supplies were required in the vineyards only on a seasonal basis, ample manpower was usually present for the building of stone projects. (O: 35)

Achilles F. Grigsby, who arrived in Napa County in 1845 and became a County Supervisor in 1857, is credited by some as being the first to advocate use of local stone as a building material. The County's first stone arch bridge was built in 1860. The use of good quality local stone for buildings began about 1860 with the establishment of several quarries in the county. Stone work is displayed in a variety of structures in Napa Valley—in private dwellings, public buildings, wine cellars, and bridges. Most of these stone structures are still sound and in use. The most prominent and numerous are the stone winery buildings. They are described by Anne Roller Issler in the following terms: "Architecturally, the old stone wineries are the most interesting features of the county . . . the earliest wineries here were built of stone blocks quarried out of nearby hills, many borrowing in architecture from German *Schloss* and French chateau, familiar to the pioneers from Germany, France, and Switzerland."[54] (O: 35)

Stone construction was used in many of Napa Valley's commercial and public buildings, ranging from the imposing County Court House in Napa to the Roman Catholic Church in St. Helena. The abundance of natural fieldstone and inexpensive labor combined to produce many miles of stone walls, retaining walls, terracing, and fences in nineteenth-century Napa County. (O: 35)

By the turn of the century, Napa County was known as the "County of the Stone Bridge." Over 326 stone bridges and culverts were counted by 1914, including some of the largest in the western United States. Nearly all were built of quarried volcanic rock or mixed volcanic rock and sandstone. The most graceful of the structures of the period is the Pope Street Bridge in St. Helena. Built by R. H. Pithie in 1894, this bridge is currently listed on the National Register of Historic Places. Two years later, Pithie built the Putah Creek Bridge. At a cost of $19,500, this was the largest stone bridge built west of the Rocky Mountains and was referred to as the "Queen of the Stone Bridges." Presently, this three 70-foot span, native sandstone bridge lies beneath Lake Berryessa. (O: 35)

The method of building in Napa County followed a routine procedure. After the county engineer selected the site of a new bridge, the contractor would look it over, search the area for a proper stone source, and set up quarrying activity. The rough quarried stone was then carted to the site to be cut before the stones were set. (It was common for the stone masons families to camp for the summer at a bridge construction site while this process was being completed.) After the supporting masonry abutments or piers were constructed, temporary heavy timber falsework was erected in the arch shape. The arch ring itself was built of carefully hewn blocks of stone, each cut to a slight wedge shape so that the joints between blocks were at right angles to the ring. Thus, the joints are normal to the compressive force in the arch and each block is secured against falling. The arch ring was built outward from the footings to the center of the span, where the precisely shaped keystone was set into place. Earth or rubble fill was then placed to form the roadway. The fill was enclosed by retaining walls, called spandrel walls, built vertically above the edges of the arch ring.[55] (O: 35-36)

The arch shape is ideal for spans built of materials which have good compressive strength but little or unreliable tensile strength. All forces in a properly shaped arch are compressive. Early bridges were built without mortar in the joints. Later bridges used pozzuolanic or portland cements to fill joints which reduced the amount of labor needed to hew the blocks to the precise fit needed for "dry" joint arches. (O: 36)

The abundance of stone masonry bridges in Napa County is due primarily to the design efforts of Oliver H. Buckman, the Napa County Surveyor. O. H. Buckman was born near Baltimore, Maryland on December 14, 1847. In 1855, his family moved to a farm in Iowa where he lived until he entered the State University of Iowa. He graduated in 1876 with a degree in civil engineering. In 1877, Buckman settled in Napa, California. His career began as a county surveyor in 1885. In 1896, he served as deputy county surveyor for a brief period and then again became the county surveyor. He remained in this position until about the time of World War I.[56] (O: 36)

Major stone masonry bridge contractors in the Napa valley were H. W. Wing and his partner in many ventures, J. B. Newman. Both were expert stone masons who emigrated to America from England. They established the Napa Marble Works in 1878, which produced cemetery stones and vaults. J. B. Newman traveled to Europe around 1900 to study the latest techniques in stone cutting. As a result of his study abroad, Newman's work crew had the most modern and efficient tools available at that time and was regarded as the most efficient group of tradesmen in the Valley.[57] (O: 36)

The stone masonry trade existed for nearly seventy years in Napa Valley. Up to World War I, stone masonry was used in the construction of Napa Valley's bridges and buildings. Several related factors can be linked to the demise of the stonework era in the valley. These include a change in the ethnicity of the population, the absence of inexpensive labor, and changes in building technology.[58] (O: 36)

Santa Barbara County also had a tradition of stone bridge-building, which began during the period of Spanish rule. It continued through the nineteenth century, largely because local sandstone was readily available and easy to work. Stone bridge construction got new life after World War I, when the City of Santa Barbara adopted the Spanish look as its design theme for new construction. The county's leading designer of masonry arch bridges was Owen Hugh O'Neill, Jr., who served as county surveyor from 1914 to 1946.[59]

6. Suspension Bridges

In one respect, the suspension bridge is not a significant bridge type in California; very few have ever been built in the area. The quality of these bridges, however, compensates for the lack of quantity. From the pioneering spans of Andrew Smith Halladie in the 1850s to the great bridges of C. H. Purcell and J. B. Strauss in the 1930s, California engineers have left an important mark on the design of American suspension bridges. (O: 37)

The early history of metal wire suspension bridges in America is dominated by the work of Charles Ellet, Jr. and John A. Roebling.[60] Ellet is credited with introducing European ideas about wire suspension bridges to the United States in the 1830s, and with erecting the first successful span of this sort in 1842. Roebling built upon the foundation laid by Ellet, designing the first long span suspension bridge (1849), the great Niagara span (1855), and the Brooklyn Bridge (1883). (O: 37)

Andrew Smith Halladie was a contemporary of Ellet and Roebling but was, at least initially, not familiar with their work. Halladie was born in Scotland in 1836, the son of an inventor and engineer who had experimented with wire cable manufacturing in the 1830s.[61] A. S. Hallidie immigrated to California in 1852, at the age of 16. He first worked with wire cable in 1856, spinning a cable for pulling ore carts.[62] In 1857, he settled in San Francisco and established the first wire cable manufacturing facility in California. This firm was initially called A. S. Hallidie & Co., and was later called the California Wire Works. (O: 37-38)

Hallidie continued to manufacture wire cable in San Francisco until his death in 1900, all the while developing new applications for the product. His work in suspension bridge design should be understood in this context. His first suspension bridge was built in 1861, crossing the Klamath River at Weitchpect. He designed at least six more such bridges in California in the early 1860s. In 1863, he built the greatest of his structures, a great span across the Fraser River in British Columbia. With all such cases, including the Fraser River bridge, the structural metal was fabricated in San Francisco. (O: 38)

Lamentably, no surviving examples remain from Halladie's pioneering West Coast suspension bridge manufacturing and design. His experimentation in the use of wire cable is, however, commemorated by his most significant invention—the cable car system of San Francisco, first devised in 1871 and in use today. (O: 38)

Only one mid-nineteenth-century suspension bridge remained in California in 1986, the so-called Bidwell Bar Bridge in Butte County. Built in 1856, it actually predates Hallidie's involvement with suspension bridges or manufacture of wire cable. (O: 38)

This was originally a toll bridge, built by the Bidwell Bridge Company. In January 1855, the company published specifications for the structure in an area newspaper. These, signed only by the secretary for the company, are remarkably detailed, specifying treatment for the cable wires and the use of a truss stiffener for the deck. Presumably, an experienced bridge designer was involved in preparing these, but we have of record of that individual. (O: 38)

The contract for erecting the bridge went to a local firm, which in turn subcontracted to the Starbuck Iron Work of Troy, New York, for the towers and cables. The bridge had a remarkably long life. It became a county bridge in 1883 and a state bridge in 1909. It reverted to county ownership in 1938 and carried vehicular traffic until 1954. It then served as a pedestrian bridge until the late 1960s, when it was dismantled to avoid inundation by Lake Oroville. (O: 38)

The bridge was rebuilt in 1974 but not in a manner that would make it eligible for listing in the National Register of Historic Places. It was moved to a nearby but inappropriate setting, crossing a dry ravine where it once crossed a main channel of the Feather River. Worse, the structure is no longer suspended, i.e., no tensile stresses are carried by the cables. Rather, it is essentially a trestle, supported by a series of wooden bents. The cables and towers were rebuilt but are merely ornamental. Through this reconstruction, the California Department of Parks and Recreation rendered ineligible the last remaining example of a key period and method of construction in bridge design in California. The Bidwell Bar Bridge is mentioned only to establish a historical context for other suspension bridges. (O: 38-39)

When Halladie stopped designing suspension bridges after the Civil War, there followed a period of nearly eighty years in which very few suspension bridges were constructed in California. California has no long span suspension bridges from what might be called the middle period of suspension bridge design in the United States, between the pioneering work of Roebling and Ellet in the 1850s and the resurgence of suspension bridge design in the 1930s. During this middle period, many of the greatest engineers in the United States were involved in designing suspension bridges—John Roebling, J. A. L. Waddell, Ralph Modjeski, Gustav Lindenthal, O. H. Ammann, and others. During this period, many great spans were designed, particularly the set along the East River in New York City. Most major technical and aesthetic problems posed by the suspension bridge were resolved during this period. (O: 39)

California does have a small body of representatives from this middle period, but these are highly specialized applications of suspension bridge technology. What emerged was a class of bridge called the small suspension bridge. Using the length of main span and suspended dead load per linear foot of bridge and incorporating a stiffening truss into the floor system, an engineer could obtain a bridge suitable for light highway traffic. It was economical, simple to design and erect in the remote and rugged areas of California. (O: 39)

A local county surveyor or engineer could construct such a bridge with minimal equipment. The little power required was supplied by an ordinary farm tractor running along the road, and to which was attached the end of the hoisting rope. Two gin poles picked up conveniently at the location, were used in setting the towers and hoisting the main cables. All other material, timber and steel, was readily handled into position by the erection gang. This gang of bridge men was usually recruited from local labor, and except for the supervision, no previous experience was needed. Three small suspension bridges were determined eligible in 1986—the Iowa Hill Bridge, the Upper Mattole Schoolhouse Bridge, and the Colfax-Forrest Hill Bridge, all representative examples of small suspension bridge types built during this middle period. (O: 39)

While California has no major suspension bridges from this period, it did benefit from lessons learned elsewhere. These lessons helped guide construction of two of the most successful suspension bridges in the world—the Golden Gate Bridge, which has been determined eligible for the National Register, and the San Francisco-Oakland Bay Bridge, which is listed in the register. These bridges are discussed here to help establish the historical context for other bridges. (O: 39)

Planning for the Golden Gate and Bay bridges began long before either was constructed. Vague schemes for bridging the San Francisco-Oakland and the San Francisco-Marin crossing surfaced almost as soon as settlement began on the remote San Francisco Peninsula. These plans were taken more seriously after 1910 when the technical feasibility of long suspension bridges had been demonstrated. Leaders in the San Francisco bay area were in agreement that the bridges could and should be built by the early 1920s. Another decade would pass, however, before the many interested parties could agree on particular designs and financial arrangements. By coincidence, two very different financial agreements were reached about the same time, making possible concurrent construction of the two massive structures. (O: 40)

The Bay Bridge benefited most directly from the earlier efforts of suspension bridge engineers on the East Coast. The City of San Francisco conducted hearings on proposals for a private toll bridge to Oakland. Many experienced engineers submitted plans—Ralph Modjeski for a steel truss bridge, J. B. Strauss for a cantilever and bascule bridge, C. E. Grunsky and J. A. L. Waddell for suspension spans, and Gustav Lindenthal for steel truss spans.[63] In 1927, the San Francisco Board of Supervisors appointed a three-man board of engineers to study these proposals and to propose a preferred alignment. This board decided upon the two-bridge approach—Oakland to Yerba Buena Island, Yerba Buena Island to San Francisco—that was ultimately built. (O: 40)

When the State of California took over the project, Chief Engineer C. H. Purcell adopted the team design approach that had characterized Division of Highways work since the early 1920s. In creating an Engineering Board, he drew from his own staff in state service, as well as Modjeski, Dean Charles Derleth, and others who had proposed private bridges. (O: 40)

By 1931, the Engineering Board has decided upon the essential components of the Bay Bridge—cantilever spans across the eastern shipping channel and double suspension spans to the west. It is this latter element—two separate suspension bridges joined by a central man-made anchorage—that is the most significant innovation of the Bay Bridge in suspension bridge design. (O: 40)

In contrast to Purcell's team concept, design work on the Golden Gate Bridge was dominated by a single engineer, J. B. Strauss. In 1919, Strauss, already one of the most successful bridge engineers in the United States, was but one of several to submit preliminary plans for the Golden Gate crossing. His 1919 plan called for construction of what David Powden calls "one of the most monstrous bridges ever conceived"[64]—a massive cantilever carried on suspended cables. (O: 40)

This plan and others were ignored through the 1920s, although Strauss' plan was singled out for scorn by many San Franciscans. Strauss never forgot this lesson and thereafter made aesthetics one of the principal design considerations for the Golden Gate Bridge. He also became obsessed with the project, moving to San Francisco in 1921 and devoting a large part of his time to designing and advocating the bridge. (O: 40-41)

While Strauss made the Golden Gate Bridge into something of a personal mission, he was nonetheless a good bridge engineer who learned from others. His debt to other suspension bridges built in the 1920s and early 1930s can be seen in structural as well as aesthetic areas. (O: 41)

He learned, from the rejection of his earlier hybrid design and from the success of other designs, that architectural treatment was of special concern in a large suspension bridge, owing to the scale of the structure and to the inherently pleasing form of the suspended cable. He relied on the architect, Irving F. Morrow, for many important elements of the structure. Morrow and Strauss incorporated key elements from two 1931 structures by D. B. Steinman, elements which greatly enhance the beauty of the Golden Gate Bridge. First, they included Vierendeel truss supports on the upper towers, an element first used on Steinman's Waldo-Hancock Bridge. Second, they sheathed the trusswork in inflected steel, similar to Steinman's St. John's Bridge, giving to the towers rich shadows and depth. (O: 41)

In the final analysis, the bridge was the work of Strauss, Morrow, and Clifford Paine, Strauss' chief assistant. It success is attributed to many factors—the inflections of the steel, to the natural beauty of the Golden Gate, the dramatic length of the bridge, and the height of its towers. Whatever the combination of factors, the Golden Gate Bridge is enormously appealing to engineers and to the general public and is one of the most popular bridges in the world. (O: 41)

7. Steel Girders and Steel Arches

Lacking a strong local steel industry, Californians have rarely used steel as the primary bridge-building material. Even in the post-war freeway era, when the steel girder freeway overcrossing proliferated elsewhere, relatively few steel girder spans have been built in California. Steel arch bridges are even less common. Nonetheless, thirty steel girder and seven steel arch bridges were inspected as part of the 1985-86 survey (O: 41)

As a whole, California steel girder bridges lacked the engineering boldness and architectural distinction that characterize other types of bridges in the state. Most were short spans and suffered from the inherent aesthetic limitations of the riveted steel plate girder bridge. The three steel girder bridges determined eligible in 1986, all built in the mid-1930s, proved exceptions to this rule because of great beauty and boldness. (O: 41-42)

The Smith Point Bridge (4C-239) was built by the Division of Highways in 1934 across the Eel River. It was an award-winning structure the year it was built, on the basis of both engineering and architectural considerations. This structure was a continuous steel plate girder, with a total length of 555 feet and two main spans of 120 feet each. The plate girders were haunched (i.e. shallow arched), accounting for the pleasing profile, as recognized by the American Steel Institute of Steel Construction in its 1934 awards for the "Most Beautiful Steel Bridge." The structure was also recognized as the first continuous steel girder bridge in the United States built on a curve.[65] (O: 42)

The Figueroa Street Viaduct, built in 1936, was similar in appearance to the Smith Point Bridge, being a haunched continuous steel plate girder bridge. This structure was distinctive in two major respects. First, its principal span of 200 feet was an exceptional achievement in this type of structure. It was reported to be the longest steel girder span in the United States at the time it was built. (O: 42)

Second, the bridge was literally and figuratively a link between two generations of transportation systems in Los Angeles. It was originally planned in the late 1920s, when City officials looked to a system of major boulevards and river viaducts as an answer to persistent traffic problems in the downtown area. Most of the viaducts from the late 1920s were determined eligible for the National Register in 1986. For various reasons, however, the Figueroa Street Viaduct was not built until the mid-1930s. By this time, many officials in the city and the State Division of Highways had turned their attention to the so-called "parkway," or freeway, as the solution to many of the transportation problems in the area. By 1936, the first of these, the Arroyo Seco Parkway, was nearly completed. The Figueroa Viaduct was finally built, not at a conventional viaduct, but as a high-speed access from Los Angeles to the beginning of the Arroyo Seco Parkway. After World War II, both the viaduct and the north end of Figueroa Street were simply included within the freeway, becoming the link between the Arroyo Seco Parkway and the Harbor Freeway.[66] (O: 42)

The Sunset-Silver Lake Bridge (53C-136) was a more modest steel girder from a technological perspective, but it was an exceptional structure from an aesthetic standpoint. During the 1930s, the City of Los Angeles, in one of many major transportation improvement programs, established grade separations along several major boulevards, most notably along Sunset Boulevard. These grade separation structures speeded up traffic to levels approaching that of a controlled access highway. Consistent with design principles applied on a grander scale with the Los Angeles River viaduct program, city engineers made liberal use of applied decoration to beautiful these otherwise humble grade separation structures. The Sunset-Silver Lake Bridge was the most successful of these many structures. (O: 42)

The seven steel arch bridges in California were for the most part constructed after 1945. Several of these, such as the 1967 Cold Spring Arch (with a main span of 700 feet), will one day surely be listed in the National Register. The only steel arch determined eligible for the register in 1986 was the Sixth Street Viaduct, one of nine viaducts across the Los Angeles River. (O: 43)

The Sixth Street structure was the last of the viaducts to be designed and constructed and was by far the largest and most expensive of the group. It was classified a steel arch by convention in that its largest spans were twin 150 foot steel through arches. The remainder of-the structure, the total length of which is 3,546 feet, comprised concrete T-girder spans. (O: 43)

In addition to being the only steel arch bridge determined eligible for the National Register in 1986, the Sixth Street Viaduct represented a distinctive accomplishment in bridge architecture. Its detailing was Streamlined Moderne, as exemplified most distinctly in the large pylons at the western portals, in the decorative fascia girder, in the inflection at the river piers, and in the light standards throughout the structure. Other California bridges incorporated Moderne elements, as in the steel sheathing for towers of the Golden Gate Bridge. The Sixth Street Viaduct was exceptional, however, for the integrated use of Moderne detail. (O: 43)

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F. ASSOCIATED PROPERTY TYPES

Introductory Note

The typology used here comes from the eligibility studies completed in 1985 and 1986. Truss bridges thus include covered, movable (bascule, swing, lift), and cantilevered bridges, types sometimes categorized separately. Only the four bridge types most frequently occurring in the 1985-86 surveys—truss, concrete arch, concrete girder, and stone masonry—are discussed below. Omitted are other surveyed types: concrete slab, canticrete, suspension, steel girder and stringer, steel arch, and timber stringer bridges. The multiple property format allows these types of bridges to be added later in an amendment to this submission.

1. Truss Bridges

Description. A truss bridge, whether timber or metal, is defined by a web of straight, relatively short pieces that are arranged in triangles and form each wall of the structure. The web is tied to an upper and lower chord. Transverse beams link the walls. Wood truss bridges have roofs and walls. On older bridges bolts or cylindrical pins hold the elements together. Riveted connections with gusset plates are used on later metal bridges.[1]

Truss bridges are categorized in two familiar ways. The first looks at the relative positions of the walls and the deck. In a "through truss" or a "pony truss" the deck runs between the walls. In a through truss transverse beams link both the upper and lower chords. In a pony truss, usually used for shorter spans, only the bottom chords are linked. In a "deck truss," a much rarer form in California, the deck is atop the truss. In addition, the state has at least one example of a "half-through truss," in which the deck is carried about half the distance between upper and lower chords.[2]

Truss bridges are also classified by the configuration of the elements that make up the truss. Dozens of variations have been created, usually named after their original designers. The variations aim to increase strength, lengthen spans, or lower costs. The Pratt truss is the most common in California. Usually used for spans under 150 feet, it has heavy vertical members and horizontal upper chords. The basic design has been modified in many different ways to allow for longer spans. California also has around 30 examples of the Parker truss. Bridges of this form use a polygonal top chord. The Warren truss is seen on bridges constructed in the 1920s and 1930s. It is distinguished by its elimination of vertical truss members and reliance on the equilateral triangle to withstand loads.[3]

Metal trusses are routinely used for movable bridges across navigable waterways. These bridges are of three types: the swing bridge, which rotates on its center pier; the bascule bridge, which lifts up on a hinge and may have one or two leaves; and the lift bridge, which has a central span that is suspended between two towers and rises uniformly. In California movable bridges are found primarily in the Sacramento-San Joaquin delta.[4]

Covered bridges now remain only in unpopulated rural areas, where the undeveloped surroundings add to their aesthetic appeal. Metal truss bridges appear in a variety of settings. Replacement of truss members is probably the most common alteration. For covered bridges replacement of roofs and sheathing is also typical.

Metal truss bridges are associated not only with the evolution of bridge construction in California (the subject of the historic context) but also with the development of California's highway system, within which bridges play an essential role. Highways and bridges link communities of all sorts and support a myriad of activities that require transportation of people and materials.

Significance. Like all bridge types that have enjoyed popularity California, truss bridges illustrate the design capabilities and fabrication skills of the state's bridge builders. Each represents a material response to a specific road-construction problem. If erected of timbers and covered, they provide rare examples of a construction method that has not been widely used for more than a century. If constructed in the late nineteenth and early twentieth centuries, they illustrate the work of various construction firms. If put up from around 1910 onward, they show the design capability of state and county engineers. Usually thought of as railroad bridges, truss bridges also played an important role in California road building. Hundreds were constructed throughout the state. Metal truss bridges proved especially useful for inconspicuous locations where aesthetic considerations were of less importance than cost and functionality. Although the metal truss was, by the 1930s, seldom used for fixed bridges of small to moderate length, it continued to be put up for special purposes. Examples are swing bridges, bascules, and long-span cantilevers. Section E discusses truss bridges in greater detail.

Registration Requirements. Truss bridges were considered for National Register eligibility under Criterion A and Criterion C. An eligible bridge possessed in varying degree each of several qualities: age, association with an important builder or designer, multiplicity of spans, length, unusual characteristics, attractiveness of structure and setting, historical importance, rarity, and integrity. A point-scale was established for each quality. The maximum possible point score for any bridge was 100. An eligible bridge needed to receive about 43 points. Section G explains the evaluation system in detail. The Keeper of the National Register approved this general approach in 1985 and determined that all of the 72 truss bridges evaluated as eligible for the register did meet standards for listing in the register.

2. Concrete Arch Bridges

Description. Concrete arch bridges fall into one of two categories: closed spandrel or open spandrel. Bridges in the first group have walls that fill all the space between the arch or arches and the abutments or piers. The deck rides atop the arch barrel and the fill that has been placed between the spandrel walls. Open spandrel bridges have walls composed of pillars usually topped by small arches. The spandrel walls may continue over the top of the main arch or arches. The barrel of the arches is usually formed by discrete beams that extend the width of the bridge. The deck rests upon the beams that connect the pillars and perhaps, depending on the design, upon the arch ribs. As a rule, open spandrel bridges have longer spans and many more spans than closed spandrel bridges.[5]

Concrete is a less obtrusive material than stone or steel, making the arch (or usually a series of arches) the dominate design element in concrete arch bridges. The arches take several forms, including semi-circular, segmental, elliptical, and parabolic. The plasticity of concrete allows for the inclusion of various decorative elements. These are often of classical inspiration. The parapet wall that lines the deck may incorporate a balustrade, for example, or the pillars may be topped by capitals. Settings are both rural and urban. Typical alterations are the repaving of the deck and the replacement of the parapet walls.[6]

Concrete arch bridges are associated not only with the evolution of bridge construction in California (the subject of the historic context) but also with the development of California's highway system, within which bridges play an essential role. Highways and bridges link communities of all sorts and support a myriad of activities that require transportation of people and materials.

Significance. Like all bridge types that have enjoyed popularity California, concrete arch bridges illustrate the design capabilities and fabrication skills of the state's bridge builders. Each represents a material response to a specific road-construction problem. In addition, concrete arch bridges, along with other concrete bridges, show the development in the use of an important new building material. As the twentieth century progressed, reinforced concrete came to dominate bridge building in California. In innovation as well as sheer numbers, the state led the nation in the use of concrete for bridges. Concrete arch bridges have been constructed in many different settings and in a variety of lengths. They have added great flexibility to road building in the state. Most notable are long, open spandrel bridges constructed in rugged environments. Such a bridge often displays a graceful appearance that belies its functional intent. Section E provides much more information about the evolution and use of concrete bridges in California.

Registration Requirements. Concrete arch bridges were considered for National Register eligibility under Criterion A and Criterion C. An eligible bridge possessed in varying degree each of several qualities: age, association with an important builder or designer, length of the main span, total length, technological importance, special features (ornament, wall treatment, pedestrian amenities), attractiveness of structure and setting, historical importance, and integrity. A point-scale was established for each quality. The maximum possible point score for any bridge was 100. An eligible bridge needed to receive about 48 points. Section G explains the evaluation system in detail. The Keeper of the National Register approved this general approach in 1985. In 1986 State Historic Preservation Officer and the Federal Highway Administration determined that all of the 75 concrete arch bridges evaluated as eligible for the register did meet standards for listing in the register.

3. Concrete Girder Bridges

Description. Concrete girder bridges employ a simple design. Several large concrete girders extend from abutment to abutment for single-span bridges and from abutment or pier to pier for multi-span bridges. The deck rests upon the girders. Because the it overlaps the outermost girder, the deck on a single-span bridge often appears to be without support. On multi-span bridges the pier is a conspicuous part of the support structure and is likely to display some decorative elements. The deck area may also have ornamental details, such as pylons, lanterns, or embellished railings. Lengths of concrete girder bridges vary considerably, from near-culverts just over 20 feet to monumental structures stretching 500 feet or more. Settings also differ widely. Rail replacement and deck resurfacing are the two most typical alterations.[7]

Concrete girder bridges are associated not only with the evolution of bridge construction in California (the subject of the historic context) but also with the development of California's highway system, within which bridges play an essential role. Highways and bridges link communities of all sorts and support a myriad of activities that require transportation of people and materials.

Significance. Like all bridge types that have enjoyed popularity California, concrete girder bridges illustrate the design capabilities and fabrication skills of the state's bridge builders. Each represents a material response to a specific road-construction problem. In addition, concrete girder bridges, along with other concrete bridges, show the development in the use of an important new building material. As the twentieth century progressed, reinforced concrete came to dominate bridge building in California. In innovation as well as sheer numbers, the state led the nation in the use of concrete for bridges. Concrete girder bridges, introduced around 1910, have been constructed in many different settings and in a variety of lengths. They have added great flexibility to road building in the state. Multi-span bridges most clearly show the capabilities of the form. The greatest use of concrete girder bridges, however, was in extending roads across short spans. Short and simple bridges of this type were routinely constructed by all levels of government across the state. Section E provides much more information about the evolution and use of concrete bridges in California.

Registration Requirements. Concrete arch bridges were considered for National Register eligibility under Criterion A and Criterion C. An eligible bridge possessed in varying degree each of several qualities: age, association with an important builder or designer, length of the main span, total length, technological importance, special features (ornament, wall treatment, pedestrian amenities), attractiveness of structure and setting, historical importance, and integrity. A point-scale was established for each quality. The maximum possible point score for any bridge was 100. An eligible bridge needed to receive about 48 points. Section G explains the evaluation system in detail. The Keeper of the National Register approved this general approach in 1985. In 1986 State Historic Preservation Officer and the Federal Highway Administration determined that all of the fourteen concrete girder bridges evaluated as eligible for the register did meet standards for listing in the register.

4. Stone Masonry Bridges

Description. Stone masonry bridges are defined by their construction material and their use of one or more arches. Usually they are constructed of locally quarried stone, often limestone, sandstone, or volcanic tuff. Stones of the arch—the voissoirs and the keystone—are shaped and often dressed. Those in the spandrel walls and piers might be unshaped, undressed, and laid in irregular courses. The arch itself is usually semi-circular or segmental. The deck, often rising slightly toward the center of the span, tops the barrel of the arch and the fill between the spandrel walls. Parapet walls line each side of the deck, the original surface of which is now always covered in paving material. Wing walls may extend from the abutments. The lengths of stone masonry bridges vary considerably, from around 30 to 177 feet. Most have only one span. Their settings are predominately rural. Aside from the paving of decks, the most typical alterations are widening of the entire structure and altering of parapet walls.[8]

Stone masonry bridges are associated not only with the evolution of bridge construction in California (the subject of the historic context) but also with the development of California's highway system, within which bridges play an essential role. Highways and bridges link communities of all sorts and support a myriad of activities that require transportation of people and materials.

Significance. Like all bridge types that enjoyed popularity California, stone masonry bridges illustrate the design capabilities and fabrication skills of the state's bridge builders. Each represents a material response to a specific road-construction problem. In addition, as discussed in Section E, these bridges show the persistence of ancient building techniques in late nineteenth- and early twentieth-century California. Similar bridges were built thousands of years ago by the Romans and Chinese. Stone masonry bridges also exemplify a building tradition that continued, primarily in Napa County and sporadically elsewhere, long after it had been abandoned in most of the state and nation.

Registration Requirements. Stone masonry bridges were considered for National Register eligibility primarily under Criterion C. Unlike other bridges surveyed in 1985-86, they were not evaluated under the system in which important qualities (date of construction, importance of builder, length of span, etc.) were assigned points and a bridge was awarded a numerical score. Instead, an assessment of a bridge's integrity of design, materials, and workmanship was sufficient to decide whether it was eligible for the register. Nearly three-quarters of the stone masonry bridges surveyed had been severely altered over the years. Those that retained integrity were judged eligible. Section H discusses the evaluation process in greater detail. In 1986 State Historic Preservation Officer and the Federal Highway Administration determined that all of the twelve stone masonry bridges evaluated as eligible for the register did meet standards for listing in the register.

NOTES

1. "Vehicular Bridges in Arizona," Multiple Property Submission, National Register of Historic Places website < www.nr.nps.gov/multiples/64500050.pdf > , 12 February 2003, sec. F.3, p. 1.

2. Stephen D. Mikesell, *Historic Highway Bridges of California* (Sacramento: California Department of Transportation, 1990), pp. 43-70.

3. *Ibid.*

4. *Ibid.*, pp. 110-121.

5. *Ibid.*, pp. 74-78.

6. *Ibid.*, pp. 76-101, 104-05; "Vehicular Bridges in Arizona," sec. F.1, pp. 1-2.

7. Mikesell, pp. 78, 108, 160-83, *passim.*

8. *Ibid.*, pp. 32-41.

G. GEOGRAPHICAL DATA

The State of California

H. SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

This multiple property submission is based on a statewide survey of highway bridges in California undertaken in 1985 and 1986.

This survey was funded by the Federal Highway Administration (FHWA) and conducted by professional cultural resource staff of the California Department of Transportation (Caltrans). The staff of the California State Historic Preservation Officer (SHPO) was involved in review of this work at various stages in the process. Principals in the inventory were: John Snyder, Chief Architectural Historian, Caltrans; Stephen Mikesell, historian, Caltrans; and Diane Pierzinski, Associate Environmental Planner, Caltrans. (O: 8)

Identification. At the outset of the California bridge survey, Caltrans, FHWA, and SHPO staff agreed to a two-phased survey strategy. During the first year, historic trusses were identified and evaluated. Significant examples of this bridge type were included in a 1985 thematic request for determination of eligibility. The second year effort was directed toward the remaining bridge types. (O: 8)

The initial step in identifying potentially eligible structures involved separating out those structures that were clearly not eligible. The three agencies in consultation developed criteria for this initial selection. Four bridge types—trusses, masonry bridges, suspension bridges and concrete arches—were seen as especially sensitive; all known examples of these types were inventoried. For the remainder—concrete girders, steel girders, timber stringers, steel stringers and steel arches—the initial cut was made by Caltrans staff after a careful inspection of highway bridge maintenance files. Properties were eliminated when they met certain criteria: they were less than 50 years old and not exceptionally significant; they were culverts, i.e. with spans of less than 20 feet, and not significant in other respects; they were modified to such an extent that the original design integrity was lost. (O: 8-9)

Identification was made easier by the existence of a computerized log of all state and local highway bridges, maintained by the Office of Structures Maintenance at Caltrans. The survey population was further diminished by excluding pedestrian, industrial, and railroad overcrossings and other bridges that do not actually carry highway traffic. (O: 9)

Documentation. Essential data was gathered for each of the 998 bridges identified through the methods described above. This included: contractor; designer; date of construction;

location of plans; documented relocation or structural modification; function of original highway route and significance to local and state transportation. Important archives consulted include: structures document archives at Caltrans, which contains plans for nearly all state and most local bridges; state construction contracts; county and city public works records; county board of supervisors minutes and county clerk records; and archives of local historical societies and museums. This information was computerized to facilitate easy retrieval and sorting by salient attributes. (O: 9)

Evaluation. In consultation, Caltrans, FHWA, and the California SHPO agreed to utilize a quantitative evaluation system to help determine eligibility for the three largest groups of bridges—trusses, concrete arches, and concrete girders. After the initial selection, the inventory population included 432 trusses, 289 concrete arches, and 116 concrete girders. The remaining bridge categories included very few examples—35 concrete slabs, 12 suspension bridges, 11 tunnels, 47 stone masonry arches, 30 steel girders, and several types with fewer than ten representatives (steel arches, steel stringer, timber stringers, canticrete bridges, and box culverts). Caltrans staff elected to utilize traditional qualitative evaluation techniques for these latter bridge types, recognizing that the survey population was too small to produce meaningful statistics or to justify the expense of developing a formal computerized evaluative framework. (O: 9)

A large body of literature discusses the use of quantitative methods in the evaluation of historic resources, particularly with respect to historic residences, commercial structures and bridges.[1] Caltrans staff studied and tested several such systems, focusing upon those dealing specifically with historic bridges. (O: 9-10)

In consultation with FHWA and the California SHPO, Caltrans staff developed an evaluation framework that was based in large part upon an earlier system used by the Ohio Department of Transportation.[2] The Ohio system was modified, however, to reflect special circumstances in California and to correct perceived shortcomings in that earlier effort. The California system differs from the Ohio system in its treatment of integrity, significance of bridge designer, date of construction, design aesthetics and in several other areas. In making these modifications, Caltrans staff adapted some of the methods used by the Oregon Department of Transportation in its bridge survey[3] and by San Francisco Heritage in its survey and evaluation of commercial structures in San Francisco.[4] (O: 10)

Unlike bridge evaluation systems developed elsewhere, the California system utilizes different methods for the three most numerous bridge types—trusses, concrete arches, and concrete girders. Practical as well as substantive considerations guided the decision to use three quantitative systems. Separate systems fit well into the two-year schedule, allowing for completion of the truss survey prior to initiating work on the remaining types. More important, the principals in the survey felt that evaluation could be more finely-tuned when discrete systems were utilized. Any system that was so general that it could deal with divergent bridge types might fail to recognize the qualities that define significance for the examples of each type. (O: 10)

The mechanism for the evaluation system is depicted below. Each variable represents an element of bridge design or historical use which can define significance. The weighting system, i.e. the points assigned to each variable, serves two purposes: to transform ordinal into integer ratings, and to distinguish between variables as to relative importance. (T: 9)

Evaluation System for Truss Bridges (T: 10-11)

Variable	Points Assigned
1. Date of Construction	
Pre-1900	20
1900-1909	16
1910-1919	12
1920-1929	8
1930-1937	4
1937-1945	0
Post-1945	-20
2. Builder/Designer	
Major example of significant builder or designer	12
minor example of significant builder or designer	6
Not associated with significant builder or designer, or unknown	0

3. Number of Spans

1	0
2	2
3	4
4	6
5+	8

4. Length of Span (In Feet)

Pony,<60; through<125; deck<150	0
Pony,60-80; through, 125-150	4
Pony,>80; through>150; deck,>150; Half-through (all)	8

5. Special Features

Pin-Connected	4
Iron	4
Decorative features (Major)	4
Decorative features (Minor)	2

6. Aesthetics

Structural	
Excellent	5
Good	4
Fair	2
Poor	0
Setting	
Excellent	5
Good	4
Fair	2
Poor	0

7. Transportation Significance/ Historical Associations

National	10
State	7
Local	3
None, unknown	0

8. Surviving Numbers (Rarity)

1	20
2	19
...	
20	1
>20	0

9. Integrity

Location, Setting	
Excellent	0
Good	-3
Fair	-6
Poor	-9
Design, Materials, Workmanship	
Excellent	0
Good	-3
Fair	-6
Poor	-9
Feeling, Association	
Excellent	0
Good	-1

Evaluation System for Concrete Arch and Girder Bridges (O: 10-11)

Variable	Points Assigned
1. Date of Construction (Same for arch and girder)	
1910 and earlier	20
1911-15	17
1916-20	14
1921-25	11
1926-30	8
1931-37	4
1937-1945	0
1946+	-20
2. Designer (Same for arch and girder)	
Major example of a significant designer	12
Minor example of a significant designer	6
Other	0

3a. Main Span

Girder Length	Points	Open Spandrel Arch Length	Points	Closed Spandrel Arch Length	Points
≥80 feet	8	≥200	8	≥100	8
70-79 feet	5	175-199	6	75-99	5
60-69 feet	3	150-174	4	50-75	3
50-59 feet	1	125-149	3	25-49	1
<50 feet	0	100-124	2	<25	0
		75- 99	1		
		<75	0		

3b. Total Length

Girder Length	Points	Open Spandrel Arch Length	Points	Closed Spandrel Arch Length	Points
600	8	≥1000	8	≥200	8
300-599	5	500-599	5	100-199	5
200-299	3	250-499	2	50-99	2
100-199	1	<250	0	<50	0
<100	0				

4. Aesthetics (Same for arch and girder)

Structure	
Excellent	5
Good	3
Fair	1
Poor	0
Setting	
Excellent	5
Good	3
Fair	1
Poor	0

5. Technological Significance (Same for arch and girder)

Excellent	20
Very good	15
Good	10
Fair	5
Poor/unknown	0

6. Special Features (Same for arch and girder)

Feature	Major	Minor	None
Decorative Lanterns	2	1	0
Decorative railings	2	1	0
Pylons	2	1	0
Decorative treatment of spandrel area (arch) or fascia (girder)	2	1	0
Distinctive texture (rustication, stone facing, etc.)	2	1	0
Pedestrian amenities	2	1	0

Transportation Significance/Historical Associations (Same for arch and girder)

National Significance	10
Statewide Significance	7
Local Significance	3
None/Unknown	0

Integrity (Same for arch and girder)

Location/Setting	
Excellent	0
Good	-3
Fair	-6
Poor	-9
Design/Materials	
Excellent	0
Good	-3
Fair	-6
Poor	-9
Feeling/Association	
Excellent	0
Good	-1
Fair/Poor	-2

One should bear in mind that a quantitative system of this sort produces indicators, not indices, of significance. One can conclude with assurance that bridges with very high scores are quite significant, while those with very low scores are not significant. One may also discover a reliable significance threshold, a cut-off that separates significant from insignificant structures. In this system, for example, the cut-off appears to be about 43 points for truss bridges and 48 points for non-truss bridges. (T: 12, O: 13)

With any such system, however, quantitative analysis must be checked against expert opinion. With this system, for example, "length of span" is taken as a measure of the engineering difficult involved in the span. For most truss bridges surveyed, 150 feet is a reasonable test of a significant span. This same measure, however, cannot adequately value the immense engineering achievement involved in such great spans as the San Francisco-Oakland Bay Bridge or the Carquinez Straits Bridge, where individual spans greatly exceed 1000 feet. By the same token, for most concrete arch bridges surveyed, 100 feet is a reasonable test of a significant concrete arch span. This same measure, however, cannot adequately value the immense engineering achievement involved in a great span like the Bixby Creek Bridge, with a main span of over 340 feet, and a height of 260 feet above the streambed. (T: 12, O: 13)

To ensure that such extraordinary circumstances were taken into account and ensure that standards were applied consistently, the quantitative evaluations were double-checked, using more traditional, intuitive methods. (O: 13)

In addition, the less numerous bridge types—suspension, stone masonry, steel arch, concrete slab, and steel stringers—were not subjected to quantitative analysis. Data for these bridges was, however, stored in a computer file, facilitating the same kind of sorting and analysis used for concrete girders and arches. (O: 13)

The review of masonry bridges did not have the benefit of an analytical point system as was used for truss, arch, and girder bridges. Only 47 stone masonry bridges were included in the bridge inventory. To obtain information and detail, 48 additional bridges were examined. They were either culverts or bridges under private ownership. Although excluded from the inventory, they were evaluated to help establish what influence masonry structures have in the State and to identify and evaluate the stone masons who constructed them. (T: 36-37)

An early goal of the survey was the elimination of insignificant bridges. Out of the 47 masonry bridges in the survey, 17 were immediately eliminated based on their total loss of integrity. These bridges had both sides widened (usually using a different technology) and a radical railing modification. The remaining 30 were subjected to a further review process which determined: 1) if one side had been widened (sometimes the parapet railing was salvaged and moved), 2) if the railing had been modified in some fashion altering the feeling as well as design, or 3) if the bridge was less than 50 years old. These criteria eliminated another 17 bridges, leaving twelve bridges of potential for listing in the National Register. One, the Pope Street bridge, was already listed on the National Register. The remaining 12 bridges, after being reviewed on an individual basis, appeared to meet the National Register criteria and were included in the request for determination of eligibility. (T: 37)

NOTES

1. A general discussion of quantitative methods in bridge evaluation can be found in Transportation Research Board, "Historic Bridges – Criteria for Decision Making," Washington, D.C., 1983. See also, Stephen D. Mikesell, "Historic Preservation That Counts: Quantitative Evaluation of Historic Resources," *The Public Historian,* Fall 1986.

2. Ohio Department of Transportation, 'The Ohio Historic Bridge Inventory and Preservation Plan," 1983.

3. Oregon Department of Transportation, "(Draft) Historic Bridges of Oregon," 1984.

4. Michael C. Corbett, *Splendid Survivors: San Francisco's Downtown Architectural Heritage,* (San Francisco: California Living Books, 1979).

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