Historic Context Statement

Roadway Bridges of California: 1936 to 1959

Prepared for:
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Environmental Program
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CANTILEVER ABUTMENT — SPREAD FOOTING

Cover Images: Top to bottom, left to right: San Francisco / Oakland Bay Bridge, November 1936; US Highway 101 on the South Fork of the Eel River, December 1959; US Troops crossing a narrow bridge (unknown location), November 1940; East Shore Freeway, March 1950; Bess Avenue and Frazier Street Overcrossing, San Bernardino Freeway, January 1958; Four Level Interchange, Los Angeles, September 1949. These photographs were taken from the *California Highways and Public Works* published by the California Department of Public Works. The background engineering drawing was taken from the *Bridge Planning and Design Manual Volume II* published by the State of California Department of Public Works, Division of Highways, 1955 revised through 1966.

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1. INTRODUCTION AND SUMMARY

JRP Historical Consulting Services prepared this historic context statement regarding roadway bridges in California under contract with the State of California Department of Transportation (Caltrans) as part of a program to update the state's historic roadway bridge survey. This report supplements the historic contextual information prepared by Caltrans during the mid-1980s as part of the department's original historic roadway bridge survey conducted at that time. The purpose of this report is to provide a context for understanding the important historic patterns, trends, and themes in California roadway bridge construction from 1936 to 1959, thus supplying appropriate contextual data to accurately and efficiently evaluate bridges designed and built during this period for their eligibility in the National Register of Historic Places. In turn, this will assist Caltrans and local agencies comply with applicable sections of the National Historic Preservation Act and the implementing regulations of the Advisory Council on Historic Preservation pertaining to federal agency undertakings and their impacts on historic properties.

The following historic context will provide assistance in the steps required to ascertain a bridge's historic significance. Those steps include:

- identifying themes, geographical areas, and chronological periods;
- establishing how a bridge is associated with a particular theme or set of themes;
- clarifying whether a bridge is important within its historic context;
- ascertaining what physical features a bridge must possess to reflect its possible significance;
- making comparisons of bridges to others of similar type, scale, and or period.

Bridges in California that are found to meet the criteria for listing in the National Register of Historic Places are usually evaluated under two criteria: Criterion A, for their role in local or regional history, especially their contribution as links within the transportation system, and Criterion C, relating to possible significance in the field of engineering. Bridges are infrequently, if ever, found to be significant under Criteria B or D. Important historic persons associated with bridges are usually involved with their design, thus making them significant under Criterion C. Historic structures, such as bridges, can occasionally be recognized for the important information they yield, or might yield, regarding historic construction materials or technologies, thus making them significant under Criterion D. Bridges in California built during this period are extremely well documented; they are not themselves principal sources of important information in this regard. Application of National Register criteria for bridges is fully discussed in Chapter 4.

Following a discussion of some ways in which bridges may be evaluated under National Register criteria at the end of this chapter, the remainder of the report presents the context in chapters that reflect historic patterns, trends, and themes as they pertain to the possible significance of California's roadway bridges under Criterion A and Criterion C. These chapters are followed by a conclusion, and an outline of registration guidelines and eligibility thresholds for new or innovative bridge types and construction methods employed during the period 1936 to 1959. The Division of Highways and local agencies continued to build many of the other established bridge types and construction techniques in much the same way that they had prior to 1936.

Finally, other obsolete bridge types were largely discontinued during this time. A brief historic context regarding tunnels built between 1936 and 1959 is included as Appendix A. Although these structures are not bridges, for environmental compliance purposes tunnels are grouped with bridges and were thus included in the database that Caltrans provided JRP. Tunnels are also listed as a bridge structure type within the Caltrans' Structure Maintenance and Investigation Division.

Throughout this context statement, JRP has drawn conclusions regarding the locations and frequency of bridge types and materials. These conclusions are based upon analysis of a Caltrans database that included all bridges on state highways, as well as those controlled by local agencies, and that provided information on their current historic status. The separate bridge logs are publicly accessible on the Caltrans website. Caltrans had the database created for the purposes of updating the statewide historic bridge inventory. Many of the general geographical conclusions provided in this report are based on analysis of the bridge data organized by county and/or by current Caltrans District. Statements in this report made regarding the location of bridges, therefore, often directly refer to the geographic areas covered by the current Caltrans Districts and not those used, historically, by the Division of Highways during the period 1936 to 1959. The Division of Highways divided the state into districts, but some were differently configured during the period that this context statement covers. Figure 1 shows the layout of the current Caltrans districts within the state. While Caltrans maintains records on most bridges in California, there are bridges outside of its jurisdiction, such as bridges on federal or private land or those not used for or in conjunction with vehicular service. Any statistical summaries compiled for this report do not include information on bridges outside of Caltrans jurisdiction.

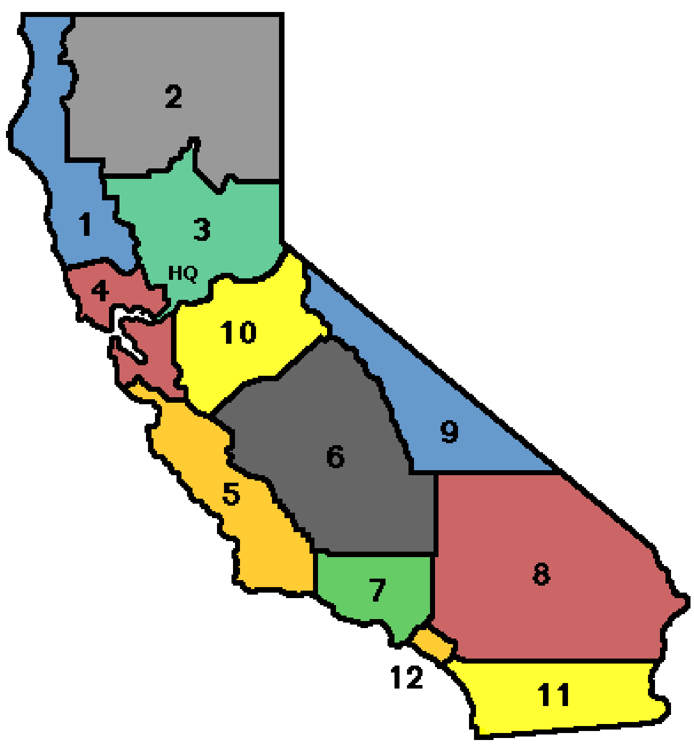

Figure 1: Current Caltrans Districts (source: Caltrans website).

1.1. Possible Significance of Bridges under Criteria A and C

Under Criterion A, California roadway bridges constructed between 1936 and 1959 are potentially significant if they are importantly associated with trends and/or events in transportation development, regional or local economic development, community planning or military history. Bridges, like other infrastructure, are inherently vital to the communities they serve. To elevate these common effects to an inappropriate level would mean that virtually any bridge would be shown to be important. To be eligible for listing in the National Register under Criterion A, resource types such as bridges and other infrastructure must have demonstrable importance directly related to important historic events and trends, with emphasis given to specific demand for such facilities and the social, economic, commercial, and/or industrial effects their construction had locally, regionally, or nationally.

Under Criterion C, California roadway bridges constructed between 1936 and 1959 may be significant for their importance within the field of bridge engineering and design. This significance derives from a bridge embodying distinctive characteristics of type, period, or method of construction or representing the work of a master engineer, designer, or builder. The historic significance of bridges within the field of bridge engineering and design has been studied in great detail in California and other states as a result of dozens of historic bridge inventories sponsored by the Federal Highway Administration during the 1970s, 1980s, and 1990s. The many historic bridge inventories have generally established salient attributes that help define significance of structures within the field of bridge engineering and design. These attributes are rarity, innovative design techniques or use of construction methods, boldness of the engineering achievement, and aesthetics. These attributes are weighed in conjunction with evaluation of a bridge's type, period, or method of construction and its association with possible historically significant engineers and/or builders.

1.2. Bridges in Historic Districts

Bridges in California have been included as contributing structures in National Register historic districts, usually when associated with the significant period of development of the adjacent properties. Bridges have been included in districts, along with adjacent buildings, as gateways to towns and as important transportation links to their regions. For example, the Lewiston Bridge (05C0032) over the Trinity River in Lewiston, Trinity County, is a contributor to the Lewiston Historic District, which includes 19 buildings plus the bridge. The district's significance derived from its association with Trinity County mining from the 1860s through the 1910s. The Lewiston Bridge, a Baltimore Petit truss built in 1901, contributes to the district as the gateway to the historic town and for it importance within the regional transportation network.[1] Bridges have also been found eligible for the National Register as part of historic districts in other types of situations. Some are included in districts that have a central core property and adjacent buildings and structures, such as the Southern Pacific Railroad Depot Historic District in San Jose (Cahill Street station) which includes The Alameda / Santa Clara Street underpass (37 0045)

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[1] C. O'Sullivan, National Register of Historic Places Registration Form, "Lewiston Historic District," October 1988; and JRP Historical Consulting Services, "Finding of No Adverse Effect, Lewiston Bridge Rehabilitation Project, Lewiston, Trinity County, California, Bridge No.5C-32," prepared for CH2MHILL and Trinity County, September 1995. The district was listed in the National Register in 1989.

The underpass structure, built in 1932, was an integral part of a new railroad station and one of various buildings and structures that served a supporting role to this urban transportation development. Still others are listed in the National Register within historic districts that are largely, or completely, comprised of bridges. One such example is the Venice Canal Historic District in Los Angeles County, which is focused around the early 20th century bridges that cross the canals near Venice Beach.

The potential for a bridge to be a contributor to a historic district depends on its historical associations or architectural compatibility with significant adjacent properties or other bridges in its vicinity. Bridges may also be eligible for listing in the National Register as part of historic cultural or designed landscapes.

1.3. Research Methods and Preparer Qualifications

This report was prepared under the general direction of JRP principals Rand Herbert and Stephen Wee. The historic context was prepared by staff architectural historian Christopher McMorris with research support from Courtney Chambers, Susan Hotchkiss, and Cindy Toffelmier. Staff historian Kathleen Kennedy provided additional research and writing assistance, and Brandon J. DeLallo, Andrew Walters, and Eric Johnson provided technical assistance. Mr. Herbert holds a M.A.T. in History from the University of California, Davis, and Mr. Wee holds a M.A. in History from the University of California, Davis. Both Messrs. Herbert and Wee each have over twenty-five years of experience in public history and historic preservation. Mr. McMorris holds a M.S. in Historic Preservation from Columbia University in New York. He has been with JRP since 1998 conducting historic inventory and evaluation studies and other historic preservation projects. Based on their levels of education and experience, Messrs. Herbert, Wee, and McMorris qualify as historians and architectural historians under the United States Secretary of the Interior's Professional Qualification Standards (as defined under Title 36, Code of Federal Regulations, Part 61). Ms. Kennedy holds a M.A. in history from California State University, Sacramento and joined JRP in 2002. Mss. Chambers, Hotchkiss, and Toffelmier as well as Messrs. Johnson and Walters are currently working on their M.A. degrees in Public History at California State University, Sacramento.

JRP conducted a majority of the research for this historic context report at the California State Library Sacramento; Shields Library at University of California, Davis; and the Caltrans Transportation Library, Sacramento. JRP also consulted its own extensive library and archive on California bridges compiled over the past decade. Additional valuable research was provided to JRP by Andrew Hope and other staff in the Caltrans Environmental Program in Sacramento.

2. CALIFORNIA BRIDGES 1936 TO 1959: IMPORTANT EVENTS AND TRENDS IN TRANSPORTATION DEVELOPMENT

Between 1936 and 1959 California's transportation system underwent a revolutionary transformation in which bridges played a critical role. Improved bridge design and construction methods helped provide safer more efficient roadways and highways in the state, required by the ever increasing volumes of private and commercial vehicle traffic. In doing so, highway and bridge engineers developed the necessary infrastructure to service regional markets and to provide the means to transport local resources widely for manufacturing and the public's consumption. Recognizing that small and inadequate older bridges needed repair or replacement to facilitate these relationships, the state, counties, and local communities sought ways to provide appropriate transportation corridors that would connect burgeoning towns and cities while accommodating the demands of an expanding state economy and growing population. Permanent and large federal funding sources for bridge construction became available during this period, at first to address unemployment during the Great Depression, and later to mobilize the nation and facilitate economic growth. During World War II and in the postwar years, bridges became crucial links in a transportation system expanded to manage the movement of military personnel and equipment between the new military facilities located throughout the state. Bridges played a critical role in the state's roadway and highway system that continued in the 1940s and 1950s as the nation's defense and growing transportation needs required reliable bridges in California to carry increasingly heavy loads and traffic volumes. Immense population and economic pressures following the war resulted in the construction of the freeway system that became a hallmark of mid-20th century California.

The following discussion divides the period 1936 to 1959 into four chronological periods. The first section addresses the renewal of roadway bridge building by the state as California emerged from the Great Depression. During the late 1930s and into 1940 and 1941, the Division of Highways began to replace hundreds of old bridges, developed plans for freeways, and constructed the state's first freeways. During this period, the federal government also required California to improve its bridges as the country prepared for war. The second section details bridge construction and maintenance during World War II, a period when there was relatively little new bridge construction with postwar construction not resuming substantially until 1947. The third section focuses on the decade immediately following World War II, when the state implemented its expansive plans for freeways and improved highways throughout the state constructing hundreds of new bridges to meet the demands of the fast-paced economic and population growth of the period. The last section explores the enormous influence that the Federal Highway-Aid Act of 1956, and subsequent legislation, had on California's bridge program. The history of California's roadway bridges from the period 1936 to 1959 is closely associated with the development of the state's road, highway, and freeway system. Most bridges built during this period were constructed with funds allocated as part of larger highway or freeway transportation infrastructure construction. Bridges played a crucial role in design and construction of the state's highway system of this period. Therefore, roadway funding, particularly the infusion of federal funding, and the development of the state's highway system are discussed below in some detail, as an understanding of these subjects is central to having a clear view of the context in which bridges from this period were constructed.

2.1. Great Depression to 1940

Following the worst part of the Great Depression in the early 1930s, bridge construction in California became an integral part of state and federal plans for economic recovery through public works projects. Government employment relief programs largely spurred this recovery, with the federal government providing much of the funding for bridges constructed in the state during this period. Infused with New Deal money, the California Division of Highways added new highways, built new bridges, and upgraded county roads into the state highway system. During this period, the state struggled to deal with its "old bridge problem" replacing inadequate often pre-automobile structures to accommodate growing volume of vehicular traffic and to address new safety issues.[2]

Of the extant bridges in California, those built before 1936 are concentrated in Northern California, particularly in the Sacramento and San Francisco regions. From the late 1930s onward, there was a distinct shift in the geographical distribution of new bridge construction in California. Of the existing bridges built between 1936 and 1940, the greatest number are in the Los Angeles area; a trend that holds true for the entire period between 1936 and 1959. Outside of the Los Angeles area, the greatest number of existing late 1930s bridges are found in the Central Valley, San Francisco Bay area, and at the north end of the state.[3]

2.1.1. The "Old Bridge Problem"

In October 1939, the head of California's Division of Highways Bridge Department, Frederick W. Panhorst, presented a paper to the Bridge Committee of the American Association of State Highway Officials (AASHO)[4] entitled "The Old Bridge Problem." Panhorst summarized the issues California faced as its first- and second- generation highway and roadway bridges, built for horse and buggy, became obsolete in the face of increased automobile and truck traffic. This problem became one of statewide importance as the Division of Highways took over control of an increasing number of county and local roads across the state. In 1933, the Division of Highways took over secondary roads that included 1,235 bridges, thirty percent of which needed immediate repairs or required load limits imposed. While many bridges were adequate, there was a distinct need for improved structures on highways used by trucks, which regularly damaged the old bridges, many of which were metal through trusses. Sometimes collisions led to collapse. Moreover, approaches were too narrow or too curved, bridge floors were not strong enough, and guardrails were inadequate. During the 1920s and 1930s, trucks had increased not only in volume on California highways, but also in size and load. By the late 1930s, semi-trailers were in common use and other large vehicles crossed California bridges applying loads

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[2] "Agency History," Department History File, 1927-1971, California Department of Transportation Library.

[3] As stated in the introduction, analysis of existing bridges is from the Caltrans database of bridges within its jurisdiction. The assessments of existing bridges are based largely on analysis data of bridge counts by district and county. The district analysis in this document is of the current Caltrans districts and not the historic Division of Highways districts from the 1930s through the 1950s. The highway districts have changed over time. District 12, Orange County for example, was part of District 7, Los Angeles and Ventura Counties, until 1988.

[4] The American Association of State Highway Officials is now known as the American Association of State Highway and Transportation Officials.

beyond their design limits. Motorists demanded wider and safer bridges permitting higher speeds and straighter roadways. Statewide inspections of structures were limited at the time, and many older structures were coming to the end of their effective life. Despite an influx of federal funding into the state for roads and bridges, there was still insufficient money to replace or upgrade all the bridges that needed improvement. Panhorst's paper advanced the need to establish more efficient bridge types, erect better bridges for the same cost, and build bridges that could withstand decreased maintenance. He noted that in California, at that time, only about five percent of the bridges were posted with reduce load limits, but that there were some counties with over thirty percent of bridges deemed unsafe and in need of complete reconstruction.[5]

One region that had many of its older bridges replaced was along the state's northern coast. To improve the road system for the burgeoning timber industry in Sonoma and Mendocino counties, for instance, the Division of Highways replaced or eliminated 46 old bridges along the Coast Highway (State Highway 56, now Route 1) between Jenner and Westport in the late 1930s and 1940. Most had been constructed before 1910 and some, like the Dark Gulch Bridge, had been constructed as early as the 1870s. Designed for horse-drawn wagons, the load capacity of these bridges was far below the standards for regular vehicle traffic, much less for loaded logging trucks. The Division of Highways constructed some of the new bridges on newly surveyed road alignments and replaced bridges with culverts where possible. The Division of Highways replaced old timber truss bridges, including both deck and through trusses, with a variety of more suitable designs. For example, the Division of Highways constructed a reinforced concrete arch at Jug Handle Creek (10 0154), shown in Figure 2, a steel Warren pony truss at Garcia River (10 0113), and a concrete box girder at Jack Peters Creek (10 0150).[6]

Figure 2: State Route 56 and Jug Handle Creek, Mendocino County, before and after new bridge constructed in 1939.

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[5] F.W. Panhorst, "The Old Bridge Problem," paper for Bridge Committee Meeting, American Association of State Highway Officials, Richmond, Virginia, October 10, 1939, introduction and 1-4; F.W. Panhorst, "Old Bridges are Menace," *California Highways and Public Works*, March 1938, 4, 5, and 9; and Steward Mitchell, "$3,000,000 Needed to Make Bridges on Secondary Roads Safe for Legal Loads," *California Highways and Public Works*, January 1935, 2-3.

[6] F.W. Panhorst, "Old Bridges are Menace," 4, 5, and 9; E.L. Walsh, "87 Bridges Replaced, Eliminated, or Strengthened on Mendocino Coast Area Highways," *California Highways and Public Works*, September 1939, 1-4; and R.P. Duffy, "Sonoma Shore Line Improvements Eliminate 18 Unsafe Timber Bridges," *California Highways and Public Works*, December 1940, 24-25.

As the link between a safe and efficient roadway system and the health of California's economy and the prosperity of its commercial life became more closely intertwined, the effects of natural disasters on bridges took on greater significance. Severe storm systems during the late 1930s severely damaged and in some instances destroyed California bridges, as shown in Figure 3. The cost of repairing and replacing damaged bridges curtailed construction of new bridges and replacement of undamaged, but outdated, bridges. At the same time, there were some cases where such destruction precipitated construction of modern structures. Northern California was hit by severe storms in December 1937, for example, and Southern California experienced strong spring storms in 1938.[7] Although the southern counties of Los Angeles, Orange, San Bernardino, Ventura, and Riverside were hit hardest, the storm system damaged or caused the collapse of bridges as far away as Monterey and Fresno. Fifteen bridges were completely destroyed and many more required rebuilding. The effects of these storms required allocations of $7 million to restore and rebuild the state's highways and bridges, roughly eight percent of the Division of Highways funding at the time. Although the state received some Federal Emergency Relief funds, the State Highway Construction and Maintenance Fund financed the restoration of many of the damaged bridges.[8]

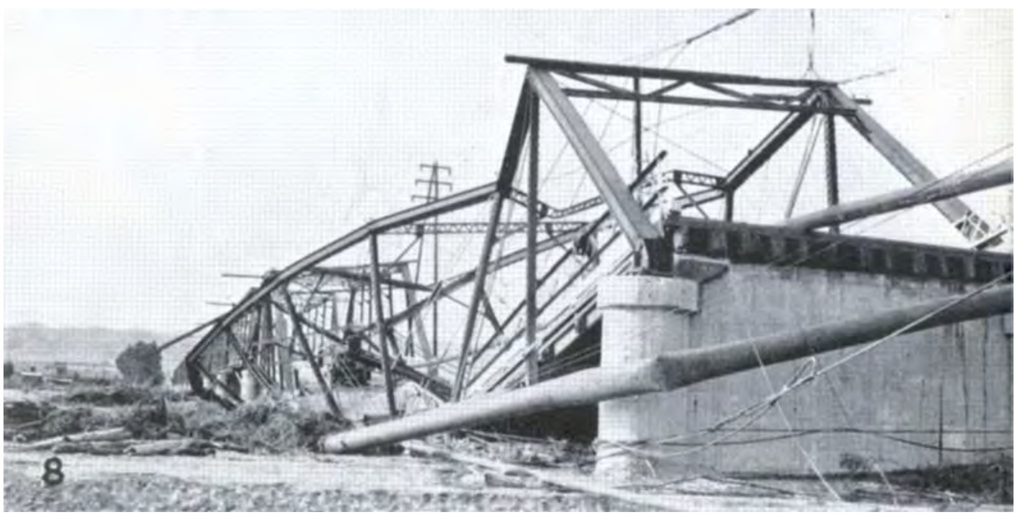

Figure 3: Santa Clara River Bridge, Ventura County, 1938

Two years later, Northern California counties again experienced flooding when the Sacramento, Feather, American, Eel, Trinity, and Russian rivers and their tributaries rose over their levees and banks in late February 1940. The highway damage totaled over $1.2 million including destroyed or distressed bridges. As a response to the 1940 floods, California's state legislature

[7] California Department of Public Works, Division of Highways, *Eleventh Biennial Report to the Governor of California by the Director of Public Works* (Sacramento: California State Printing Office, 1938), 16; and W.A. Douglass, "Damage to Bridges Heavy," *California Highways and Public Works*, April 1938, 10.
[8] W.A. Douglass, "Damage to Bridges," 10.

appropriated funds to repair and restore flood-damaged property as well as funds for construction work on the federal government's Sacramento River Flood Control Project.[9]

2.1.2. Influx of Federal Funding Stimulated Bridge Construction

California, like all states, received large allocations of federal money during the Great Depression. Many bridges constructed during the period before World War II were built, in some portion, with federal funding. During the Depression, local California governments sought to reduce their financial and road building responsibilities and lobbied the state and federal government to assume a greater burden of road and bridge improvements. In response, the Division of Highways was authorized to make improvements on city streets and county roads that connected with the State Highway System in 1931, and in 1933 the state provided further assistance with the introduction of a gas tax that reduced local property taxes.[10] From the federal government the state received funds for highway and bridge construction from the National Industrial Recovery Act of 1933, the Hayden-Cartwright Act of 1934, and the Emergency Relief Appropriation Act of 1935. Enacted to provide jobs for the millions of unemployed Americans during the Depression, these measures funded the majority of construction projects in the state. Works Progress Administration funds, for example, enabled the state to award contracts for 94 major structures between 1934 and 1936.[11] Federally funded projects tripled the Bridge Department's work load, necessitating additional personnel. In 1936, the Bridge Department employed 205 personnel, nearly double the number employed by the department just two years earlier.[12]

Federal funding slowed in the late 1930s, as unemployment dissipated, even though public demand for bridge repair and replacement continued. During this period, the Division of Highways continued to use normal state funding for highway and bridge, but required additional revenue sources as federal monies were withdrawn. In 1938, the state legislature passed a use tax of three cents per gallon on diesel fuel used by trucks and buses, for example. The revenue derived from this tax was specifically applied towards reconstruction of inadequate bridges on state highways. While the tax financed a systematic plan for replacing and reconstructing such structures, the revenue was not sufficient to replace all the state's substandard bridges.[13] Federal bridge funding from this period included aid given to the states in 1938 from the Federal Aid Highway Act, from which California received $13.5 million for construction of highways and bridges, as well as elimination of at grade railroad crossings.[14] At the same time, the Division of

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[9] California Department of Public Works, Division of Highways, *Twelfth Biennial Report to the Governor of California by the Director of Public Works* (Sacramento: California State Printing Office, 1940), 10; and "Flood Control and Restoration Bill Passed by Legislature," *California Highways and Public Works*, June 1940, 1.

[10] David W. Jones, Jr., "California's Freeway Era in Historical Perspective," (Institute of Transportation Studies, University of California, Berkeley, June 1989), 152.

[11] California Department of Public Works, Division of Highways, *Tenth Biennial Report to the Governor of California by the Director of Public Works* (Sacramento: California State Printing Office, 1936), 69-70, 19, and 85. The Emergency Relief Appropriation Act not only required that work completed with funds from the act be done by previously unemployed workers, but also stipulated their rate of pay.

[12] Division of Highways, *Tenth Biennial Report*, 1936, 19 and 65.

[13] Division of Highways, *Eleventh Biennial Report*, 1938, 13.

[14] R.F. Reynolds, "Decrease of $4,300,000 in Federal Aid to California Highway System," *California Highways and Public Works*, January 1938, 18.

Highways also applied funds from the Public Works Extension Act of 1937 to offset its diversion of construction funds to pay for emergency restoration of bridges and highways following the severe winter / spring floods of 1937 and 1938.[15] In addition to bridge construction, federal money during the late 1930s provided for studies for ambitious and innovative parkways and toll roads, which would eventually stimulate enormous construction programs of roadway grade separations structures. The state legislature, however, had yet to pass laws allowing for limited access highways, thus the state highway department continued constructing conventional highways which needed limited numbers of grade separations.[16] In the years preceding World War II, bridge construction demand grew as the country mobilized for possible war. The importance of infrastructure improvements was fully revealed in 1940 when the War Department demanded improvements to the state highway system as part of the national defense effort.[17]

2.1.3. Development of the "Freeway"

By the mid-1930s, transportation officials and many in the general public saw the need for innovations in highway design to alleviate growing traffic congestion and to reduce rising accident rates. Many of these ideas evolved to form the basis of the modern freeway system constructed in the state during the mid to late twentieth century. During the first quarter of the twentieth century, the cost of both commercial trucks and private automobiles had decreased making them available to a broader sector of the population. Between 1920 and 1930, the population of the state grew sixty percent. More than seventy percent of this new population came from migration from other states, and most of these people arrive by automobile. In 1931, for example, nearly 900,000 automobiles entered the state. Towns and commercial centers developed along major thoroughfares and at crossroads providing roadside businesses to the motoring public. The growing number of motor vehicles of the period and improved capacity of roads for speed led to increased dangers on the state's streets and roads. Roadway intersections, the interruption of the traffic flow caused by turns into driveways, and pedestrian crossings were among the most severe hazards motorists faced. Narrow lanes and bridges, along with the tight radius of bends and curves in roads that had long served horse-drawn wagons, were not suitable for vehicles traveling at speeds in excess of forty miles an hour. In 1936 the California Division of Highways reported, for example, on the difficulties of keeping pace with new road designs to match the demands of automobile technology:

> Automotive design is being advanced faster than funds will permit road facilities to match the possibilities of automobile performance, with the result that the public is not regarding the highway as a facility to be used within the reasonable limits of its capabilities. The rising accident rate furnishes cause for desiring change in roadway design.[18]

The common solutions to traffic problems were to widen or add lanes to existing roads or to create new conventional routes to divert traffic from existing routes. Although these solutions

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15 Division of Highways, *Twelfth Biennial Report*, 1940, 24.
16 David W. Jones, Jr., "California's Freeway Era in Historical Perspective," 156-7.
17 Division of Highways, *Twelfth Biennial Report*, 1940, 25.
18 Division of Highways, *Tenth Biennial Report*, 1936, 43.

responded to the volume of traffic, highway designers recognized as early as the 1920s these solutions did not adequately address safety issues. During the 1920s and 1930s, planners, engineers, and governmental officials increasingly argued for new improved highways with limited access that could move great volumes of traffic quickly. Across the country, this led to the development of various types of limited access highways, with the term "freeway" used most frequently in California to describe this new type of roadway.

The introduction of the "freeway" as a major component of the transportation infrastructure had a revolutionary impact not only on the state's highway system, but also on the number and design of bridges in California. The concept of a freeway appears to date to around 1930 when Edward Bassett, president of the National Conference on City Planning, presented the idea in an article in *The American City*. Bassett defined a freeway as "a strip of public land, dedicated to movement over which the abutting owners have no right of light, air or access" and would be free of dangerous obstacles that cluttered highways in urban areas and caused frequent stops in the flow of traffic such as parked cars. These obstacles included vehicles stopping to turn into driveways and vehicles pulling into the road from driveways or other streets.[19]

One of the major ways to reduce access while permitting continued use of adjacent city streets or county roads was the construction of bridges that either would take local traffic over or under freeway traffic. The perceived promise of limited access highways appeared to be a means to resolve the problem of moving large volumes of traffic quickly and safely through urban and rural areas. While the concept was appealing, highway planners were hampered with critical legal issues in limiting access and in securing public funding for such large-scale projects. The economics of the Great Depression prevented serious consideration of building freeways because of the immense expense of purchasing the rights of ways required, as well as the prohibitively high construction costs.[20]

In the period before World War II, various small-scale forms of limited access highways were experimented with in the United States, such as New York's parkway system and Pennsylvania's turnpike. Limited access highways were also constructed in Europe at the time, such as the *autobahn* system of Nazi Germany. Before freeways were legally defined in California, and other states, state highway agencies could only build limited access highways as parkways. Using the right of eminent domain, governments could purchase public land and construct roadways through a "park," controlling the use and access to the roadway without further legislation. This process was successfully used around New York City in the 1930s and for the Arroyo Seco Parkway in Los Angeles in 1940. Access could also be limited by charging a toll, such as on the Pennsylvania Turnpike, which was begun in 1934 and completed in 1940 using an existing right of way of an abandoned rail line for much of the road.[21] All of these roadways included many new bridges that either carried the highway over local traffic or carried local traffic over the highway.

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[19] Edward M. Bassett, "The Freeway – A New Kind of Thoroughfare," *The American City*, February 1930, 95.
[20] Herbert M. Goodwin, "California's Growing Freeway System," (Ph.D. diss., University of California, Los Angeles, 1969), 7.
[21] "Pennsylvania Turnpike Early Years," online at http://www.pahighways.com/TollHwys/PennaTPK.html, (accessed December 2002).

In California, highway planners during the 1930s realized that traffic flowed quickly between cities and was largely bottled up in urban areas. The heaviest traffic could be found in the major metropolitan areas of the state in Los Angeles and the San Francisco Bay Area, which were the preeminent commercial, manufacturing, transportation, and administrative centers of the state. Los Angeles' first attempt to build a limited access highway was on Ramona Boulevard in 1931. It was billed as the highway of the future, but was designed without formal authority to close cross streets and to limit access, and quickly demonstrated the necessity of control over development on abutting lands. In a few years the route became a commercial avenue clogged with local traffic drawn to the development that grew up around the road. The concept of the freeway gained momentum during the 1930s and it became necessary to legally define this new road type. The legislature passed a law in 1939 that recognized a freeway "as a new type of highway to which abutting property shall not have right of access."[22]

California's first freeway, the Arroyo Seco Parkway, was completed in 1940. Routed through a wash and surrounded by parklands, the Arroyo Seco (later the Pasadena Freeway), was completely protected from the conflict of having abutting lands developed.[23] This 8.2-mile freeway linked Pasadena with Los Angeles, and eventually became part of the Los Angeles region's freeway network. The freeway included over twenty new bridges to permit local traffic to cross over the new roadway. The divided highway featured reflecting signs, light standards along the route, and shrubs planted in the divider to shield drivers from oncoming headlights. It also did away with cross traffic, instead providing businesses with frontage roads and access by ramps to take vehicles on and off the freeway. The Arroyo Seco was praised as being "more convenient, comfortable and economical for motor vehicle operation than city streets of comparable traffic volume…," and was as a source of pride for the Division of Highways.[24] The advent of World War II interrupted the expansion of freeway construction, but state and local agencies continued planning for the new road type and construction quickly resumed at the end of the war.

2.2. World War II Era: 1941 to 1946

Preparations for possible war and the eventual involvement of the United States in World War II created new challenges for the California Division of Highways as mobilization necessitated immediate and widespread highway and bridge improvements. Even before the war began in Europe, the Division of Highways, in conjunction with the federal Public Roads Administration, began planning and surveying to develop a program linking California with the National Defense Highway System in order to effectively move military personnel and heavy equipment across the country. As shown in Figure 4, the Division of Highways' war preparations were well under

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[22] C.C. Carleton, "Laws Passed by 1939 Legislature Affecting State Highway System," *California Highways and Public Works,* October 1939, 12-13; David W. Jones, Jr., "California's Freeway Era in Historical Perspective," 178; and Division of Highways, *Eleventh Biennial Report*, 1938, 32. Note: The term was spelled "free-way" in this government report.

[23] David W. Jones, Jr., "California's Freeway Era in Historical Perspective," 176-8.

[24] Historic American Engineering Record No. CA-265, "Arroyo Seco Parkway," 42; S.V. Cortelyou, "Arroyo Seco 6-Lane Freeway," *California Highways and Public Works*, June 1939, 10-13; S.V. Cortelyou, "Arroyo Seco Parkway Unit Open," *California Highways and Public Works*, August 1940, 14-17; and R.E. Pierce, "Study Shows Accidents on Arroyo Seco Parkway are Less Than on Some Los Angeles City Streets," *California Highways and Public Works*, July-August 1945, 1.

way by the time the United States entered the war in December 1941. California's climate, Pacific Coast location, and available undeveloped land made it an attractive site for military training and war industries.

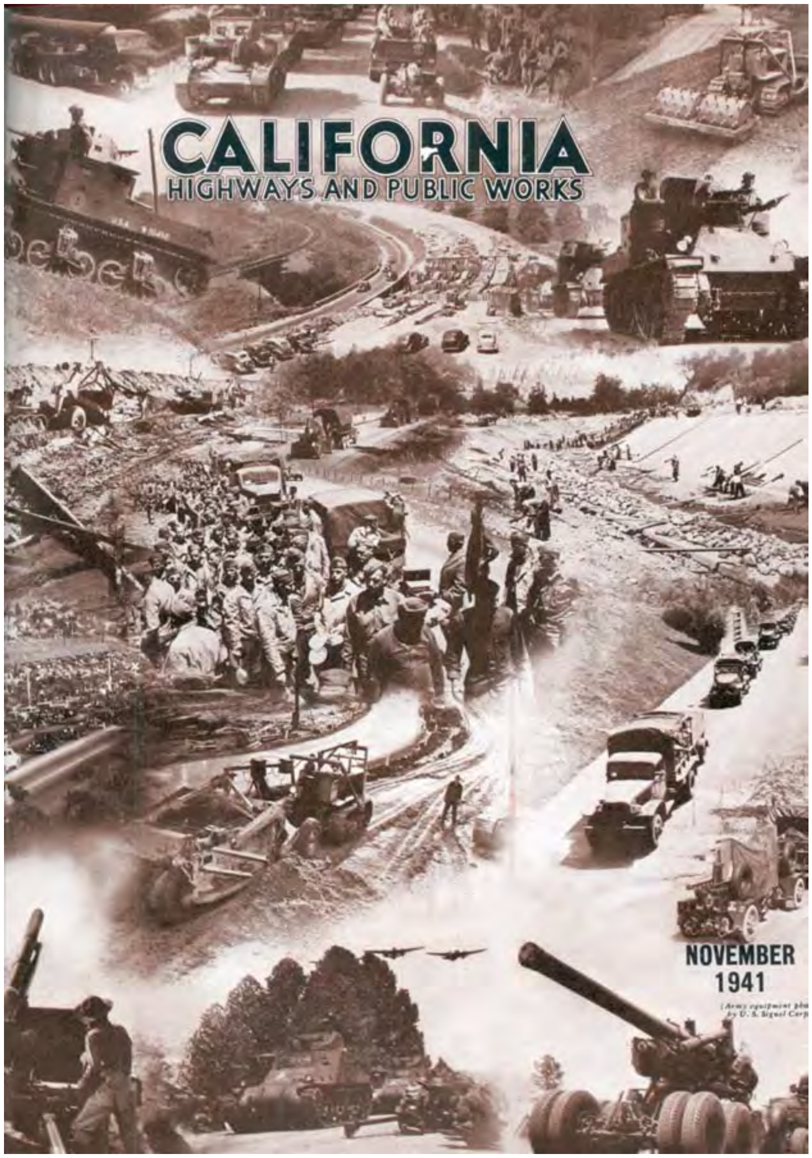

Figure 4: War preparations, *California Highways and Public Works* cover, November 1941.

As a result, the federal government located bases, airfields, shipyards, depots, and factories in the state, many of which were in Southern California and in the San Francisco Bay area. In addition to moving the military, the goal of the National Defense Highway System was to maintain roadways that could connect raw materials and agricultural products with manufacturing and industrial centers. As part of the planning process, a Division of Highways' bridge study in December 1940 listed approximately 1,500 bridges on California highways that were to be part of the strategic military highway network. The study showed that nearly one half of the bridges on highways designated as necessary for military use needed repair or needed to be replaced, widened, or strengthened to War Department standards. For security reasons during the war, Division of Highways publications provided limited indication of the state and federal governments' conclusions on where the need for National Defense Highway and military access roads was highest.[25] To make the necessary improvements to state highways required for the strategic road system in California and to build access roads to new military installations, the Division of Highways used both state revenues and regular federal appropriations including Federal Aid funds, Federal Aid Secondary funds, and Federal Aid Grade Crossing funds. Recognizing the need for additional funds to achieve highway and bridge construction defense needs, Congress passed the National Defense Highway Act of 1941 that appropriated and authorized additional expenditures for California's highway bridges. While the act eased some of the financial burden to California, the Department of Highways still needed to constantly reconsider and reevaluate the necessity of some of the proposed and planned projects in light of defense needs.[26]

During World War II, the Division of Highways, like other government entities along with private industries, was affected by the mobilization for war both in terms of personnel and materials. Maintenance and construction programs were impacted by the loss of a skilled and trained construction labor force to military service and defense work. By 1942, 1,200 employees had left the Division to enter the military or work in various defense industries. Personnel issues became so dire that by 1944, the Division was hiring high school and college age employees that were too young for the draft, and had women working in drafting rooms and other jobs typically filled by men. Most of these employees were terminated at war's end to allow returning service men regain their jobs.[27]

Scarcity of personnel and materials halted much of the scheduled repair and maintenance needed on bridges, and federal restrictions on use of structural steel, reinforcing steel, timber, and hardware practically stopped new bridge construction for all bridges except those needed for defense purposes. Bridge Department engineers adapted designs for the situation using substitute materials for new construction as well as for repair of existing bridges. Steel was in the greatest shortage as the military controlled most of its use. Plates and rolled shapes for steel bridges as well as reinforcing steel for concrete structures were essentially unavailable for bridge construction. The bridge department used salvaged steel rails from old logging railroads, for instance, to construct or repair bridges. The scarcity of nails needed for concrete forms even made unreinforced concrete structures difficult to construct. Copper was used for water stops, zinc was used in galvanizing expansion angles and railings, and aluminum was used in paint. Engineers reused of existing truss bridges, sometimes turning them upside down to fit the requirements of a new site, or had temporary timber superstructures built which could be replaced with steel when it became available. Wartime restrictions, which lasted well into

[25] F. W. Panhorst, "700 Bridges on Federal Military Highway Network in State Inadequate for Defense needs," *California Highways and Public Works*, December 1940, 1; C. H. Purcell, "Highways for National Defense," *California Highways and Public Works*, November, 1940, 1; and California Department of Public Works, Division of Highways, *Thirteenth Biennial Report to the Governor of California by the Director of Public Works* (Sacramento: California State Printing Office, 1942), 13-17.
[26] F.W. Panhorst, "700 Bridges on Federal Military Highway Network," 1; and Division of Highways, *Thirteenth Biennial Report*, 1942, 13-17.
[27] Division of Highways, *Thirteenth Biennial Report*, 1942, 40; and Division of Highways, *Fourteenth Biennial Report*, (Sacramento: California State Printing Office, 1944), 41.

1946. The postwar bridge building campaign began in earnest in 1947 resulting in the construction of some unique bridges that reflect this unusual period of innovation in bridge design and construction.[28]

As major bridge replacement projects faltered during the war years, the Bridge Department focused its limited resources on reducing its backlog of deferred maintenance. As discussed above, the state had taken over many local and county roads during the 1930s and found many of the bridges in need of repair or replacement. Most of these older bridges had not been regularly inspected or maintained by their former owners. During the war, the Bridge Department prepared inspection reports on each bridge within the state highway system. Based on the reports, all bridges were classified into groups, depending on their load capacities and structural safety. Maintenance and repair to steel truss bridges, for example, was divided into three classes: regular maintenance to preserve the structure; repair of accidental damage; and strengthening and improving clearances.[29]

It is unclear where the greatest concentration of bridges was built in the state during the war. From general accounts of bridge construction at the time, they were likely near important military and industrial centers around Los Angeles and San Francisco as well as near coastal military installations. One of the other stated goals of the period was to improve access to important agricultural areas. This spurred road improvement projects that necessitated new bridge and replacement bridge construction across the myriad of canals and creeks to allow for larger vehicles to move in and out of agricultural areas of the state, as rail transit of agricultural products declined. While the bridges on California highways from this period are associated with these contexts, the current concentration of these bridges may be, and is likely, skewed from what was actually built at the time, as many bridges were replaced in subsequent decades. Nevertheless, many are in areas of the state that directly correlate to construction patterns described above. Over 40 percent of existing World War II era bridges in California are located in coastal counties, with Los Angeles County accounting for the single greatest number of bridges from this time period by county, roughly twelve percent. Regionally, the southern Central Valley retains the greatest number of World War II era bridges, almost 20 percent, with most in that region located in Fresno and Tulare counties. Though there are bridges from this period all across the state, other local patterns bear out the statewide military context for bridge construction during this period. The military presence in San Diego during World War II, for example, likely accounts for its wartime bridges, which are roughly eight percent of the existing bridges in the state from this period.

During the war years, the Division not only concerned itself with the national defense readiness of California's roads, but it also began long-range planning for postwar expansion and construction in partnership with the federal government. This was part of a government-wide

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[28] F.W. Panhorst, "Lack of Material Forcing Engineers to Adopt Unusual Bridge Designs," *California Highways and Public Works,* February 1942, 2; and Division of Highways, *Fifteenth Biennial Report*, (Sacramento: California State Printing Office, 1946), 19-23, 45-51.

[29] F.W. Panhorst, "700 Bridges on Federal Military Highway Network," 2-3; and J.S. McClelland and W.J. Yusavage, "California Bridges, Cost and Volume of Bridge Construction: 1934-1952," *California Highways and Public Works*, January-February 1953, 31; Harvey D. Stover, "State Highway Bridge Maintenance Involves Care of 4,633 Structures," *California Highways and Public Works*, March-April, 1944, 12; and R.J. Israel, "Bridge Maintenance Practice on California Highway System," *California Highways and Public Works*, May-June, 1945, 4.

effort to face the issues of postwar recovery. Starting in 1943 the Reconstruction and Reemployment Commission began planning and implementing a comprehensive program for transition to a peacetime economy. The influx of workers to defense industries in both northern and southern California, combined with the anticipated flood of returning service personnel, created a potential postwar unemployment problem. The commission identified a highway public works program, with bridge construction, as a key component of economic development in the postwar era as the labor-intensive construction projects could absorb much of the surplus manpower. In response, the Division of Highways developed a plan to modernize the state highway system that included replacing many of the state's aging bridges. A 1943 amendment to the National Defense Highway Act of 1941 allowed federal aid to be used for the engineering and economic investigation of projects for future construction and for surveys and plan preparation, specifications, and estimates for postwar highway and roadway improvements. In the fall of 1943, the state legislature appropriated $12 million for highway plans and surveys and acquisition of rights of way for postwar construction, and the Highway Commission approved a $75 million highway construction program designed to be ready to build at the end of the war. The program eventually led to the construction or reconstruction of approximately 465 miles of state highways, including 76 bridges and grade separations of varying sizes and types.[30] Passage of the Federal Aid Highway Act in December 1944 assured California of approximately $67 million of federal funds to be spread over a three-year period for highway construction. Of primary importance, the act provided for the development of a national system of interstate highways, which in California totaled 2,820 miles, connecting major metropolitan centers. It also provided funding for construction and maintenance of a secondary or feeder network of highways designed to connect rural areas to urban centers, complementing the primary interstate highway system.[31]

2.3. Postwar Period: 1947 to 1955

Following World War II, California and the United States began a period of enormous prosperity and expansion. The state's economy grew and ever-increasing birth rates and migration into the state expanded California's population from just under seven million in 1940 to 10.5 million in 1950 and nearly 16 million by 1960. Perhaps more than any other state in the country, California linked its fate to its transportation infrastructure. The progress was most vivid in California's metropolitan areas and encouraged the shift in population and wealth to the state's urban centers. Both in response and as a contributor to the economic recovery and growth of the period, the state built hundreds of miles of highways and thousands of bridges. The state's expanding private defense industry and the military's extensive presence in California brought jobs and prosperity to the state at the same time the state's agricultural output increased and the state's vast timber resources were tapped to satisfy the demands for lumber of the boom in postwar construction. Federally sponsored programs provided low interest housing loans that resulted in vast suburban construction programs, beyond the reaches of public transportation infrastructure,

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[30] "$87,829,500 Provided by Legislature for Postwar Reemployment, Reconstruction and Readjustment," *California Highways and Public Works,* Sept.-Oct., 1943, 1; and C.H. Purcell, "Defense Highway Program in California Reached Total of $52,880,000 August 1, 1942," *California Highways and Public Works,* August 1942, 1, 11, 18.

[31] Division of Highways, *Fifteenth Biennial Report*, 1946, 19-23, 45-51; Division of Highways, *Thirteenth Biennial Report*, 1942, 16-17; California Department of Public Works, Division of Highways, *Fourteenth Biennial Report*, 15; and California Department of Public Works, Division of Highways, *Fifteenth Biennial Report*, 14.

necessitating highway and freeway construction as commuter thoroughfares. Furthermore, automobiles and trucks continued to supplant railroad passenger travel and freight shipment during this period as Californians chose to ride in their cars, eschewing busses and trains, and industrial companies chose to truck goods from point to point over the state's highways. Finally, some of the same attitudes that attracted the military to California, its natural resources, climate and scenery, induced tourists to visit and enjoy the state's natural beauty on remote scenic highways along the California coast or in its mountains. All of these historic events and trends had profound effects on highway and bridge construction in California during the decade following World War II.[32]

The state's growing urban and suburban populations, increased prosperity, concentration of military production and heavy industry resulted in greater numbers of vehicles and increase in traffic in California's urban centers. Because of these factors, it is not surprising that the heaviest concentrations of bridges constructed during this period are found in and around Los Angeles and San Francisco. There was also a great demand for new bridges in the Central Valley as the state's freeway system began to take shape narrowing the time traveled between sparse and scattered settlements to the urban centers. New roads and bridges were constructed to permit greater access to the state's most important agricultural areas, including those along the Central Coast. They also provided access to timber stands at the north end of the state where many bridges from this period remain. The improved high system linked ever more tightly the resource-based economy of the countryside in peripheral regions of California to the financial, industrial, and urban centers of the state.

2.3.1. Funding for Postwar Bridge Construction

To meet the demands of the spectacular urban-industrial growth in the state following World War II, the Division of Highway and local agencies needed substantial and stable sources of funding for street, road, highway, and bridge construction programs. California continued to receive some federal funds from the Federal-Aid Highway Act of 1944, but with uncertain future funding from Washington the state legislature established two committees in 1945 to study the state's transportation funding needs. The work of these committees resulted in passage of the Collier-Burns Act of 1947, which became one of the most influential pieces of state legislation for California's highway system as it was the first concise, dependable, and large scale capital

[32] Andrew F. Rolle, *California A History*, (New York: Crowell, 1969), 595, 598, 602; Warren A. Beck and David A. Williams, *California: A History of the Golden State*, (New York: Doubleday, 1972), 435; Ralph J. Roske, *Everyman's Eden*, (New York: Macmillan Company, 1968), 529; and Richard B. Rice, William A. Bullough, Richard J. Orsi, *The Elusive Eden: A New History of California*, 2nd ed., (New York: McGraw Hill, 1996), 498; William H. Chafe, *The Unfinished Journey: America Since World War II,* (New York: Oxford University Press 1986), 117, 123; Richard L. Forstall, "California Population of Counties by Decennial Census: 1900 to 1990," Population Division, US Bureau of the Census, March 27, 1995, accessed October 2002 online at: www.census.gove/population/cencounts/ca 190090.txt; Kenneth T. Jackson, *Crabgrass Frontier: The Suburbanization of the United States*, (New York: Oxford University Press, 1985), 112, 123, 233, 241; Tom Lewis, *Divided Highways: Building the Interstate Highways, Transforming American Life*, (New York: Penguin Group, 1997), 85.

investment program for highway and bridge construction in the state's history.[33] Passage of this act reflected a sizable commitment by Californians to improving the state highway and roadway network. The bill was named for Randolph Collier, a state senator representing Del Norte and Siskiyou counties who presided over the Committee on State Highway Finance, and Assemblyman Michael Burns, whose constituents resided in Del Norte, Humboldt, and Siskiyou counties. The law increased gasoline and diesel fuel taxes, increased vehicle registration fees, and imposed operator's and chauffeur's license fees. There was also a new procedure for taxing commercial vehicles. These funds were largely dispersed directly to cities and counties for road construction and maintenance, with one third of the funding allocated to the state. The Collier-Burns Act also allotted funding for long term planning, and directed the reorganization of the Division of Highways. New departments were set up and five assistant state highway engineers chosen to supervise operations, administration, planning, personnel, right of way, and bridges. Proponents held that reorganizing the Division of Highways was necessary to address increasing traffic congestion and highway hazards as the state's population and economy soared.[34] The Collier-Burns Highway Act had a real and immediate effect, as well as long lasting repercussions on the quality and organization of roads, highways, and bridges of California. In 1949, the first full fiscal year after the Collier-Burns Act was enacted, cities experienced an increased allocation of highway, road, and bridge funds that was three times greater than monies received previously. Furthermore the act provided that the state take over responsibility for state routes within city limits, thereby reducing the number of streets under the cities' supervision. Because each city had more money to spend on fewer streets, the quality of urban streets and bridges rose. Cities and counties were able to focus on other important routes, and urban highways and bridges were built to the state's increasingly unified design and construction practices. In the 1950s further legislation advanced the development of California's highways, building on the foundation provided by the Collier-Burns Act. [35]

At the same time the state began funding highway and bridge construction on a large scale through the Colliers-Burns Act, the Division of Highways and counties were able to build new

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[33] Eleanor N. Wood, "California: Mud to Megalopolis: A History of the Division of Highways," Department History File, 1927-1971, California Department of Transportation Library, 13; and David W. Jones, "California's Freeway Era in Historical Perspective," 189-192.

[34] David W. Jones, "California's Freeway Era in Historical Perspective," 189-192; Capitol Museum, Sacramento, California, "California Legislature: Past and Present," (accessed November 2002) online at: http://www.capitolmuseum.ca.gov/english/legislature/history/year1943.html; Right of Way Department Standing Committee on Education, "A Brief History of the California Division of Highways and the California State Highway System," Educational Training Program Text, 1960, n.p., Department History File, 1927-1971, California Department of Transportation Library, 17-18; and "Legislation Provides $76,000,000 Annually For New Construction on California State Highway System," *California Highways and Public Works*, July-August 1947, 1-2, 7, 26; California Department of Public Works, Division of Highways, *Fifth Annual Report to the Governor of California by the Director of Public Works*, (Sacramento: California State Printing Office, 1952), 139; California Department of Public Works, Division of Highways, *Sixth Annual Report to the Governor of California by the Director of Public Works*, (Sacramento: California State Printing Office, 1953), 157; and California Department of Public Works, Division of Highways, *Fourth Annual Report to the Governor of California by the Director of Public Works*, (Sacramento: California State Printing Office, 1950), 97.

[35] *Third Annual Report to the Governor of California by the Director of Public Works*, Jan. 1950, 67; David W. Jones, "California's Freeway Era in Historical Perspective," 195; Jeffery Brown, "Statewide Transportation Planning in California: Past Experience and Lessons for the Future" discussion paper California Transportation Futures Conference. Institute of Transportation Studies, University of California, Los Angeles (November 13, 2000), 18.

bridges to address growing demands at the local level. The Federal Aid Highway Act of 1944 and the state's County Highway Aid Act of 1945 provided counties funding to replace structurally inadequate bridges, which accounted for roughly half of the bridges located on county roads at war's end. The Division of Highways organized a new section under its engineer for Federal Secondary Roads, and the Bridge Department assigned a senior bridge engineer to assist counties. The state helped counties select the optimal bridge sites and designs and encouraged, but did not require, the use of uniform statewide standards. The Division of Highways reviewed county plans, estimates, and specifications and helped resolve construction problems and maintenance issues. Counties prepared bridge plans using their own engineers or consulting engineers. Most of these bridges were constructed to allow passage for the newer larger trucks and other heavy loads not permitted on older structures. In rural and forested counties, many of the replacement bridges constructed at this time were to help improve transportation of agricultural and timber products or livestock to market, and in urban areas, cities and counties built new bridges to improve transportation in industrial areas. Counties built some bridges to improve the link between new suburban residential areas to city and town centers. The state, cities, and counties built others as grade separations at railroad crossings, to bypass downtown streets, or with movable spans navigable waterway. To a lesser degree, counties at this time were also considering improved access to recreational areas.[36]

2.3.2. Freeway Construction

The number of bridges built in California grew enormously during the post-World War II period. This was largely because of the development of the state's freeway system, which required grade separations with local roads and streets. As noted the state considerably increased funding for highway and roadway projects, particularly through the Collier-Burns Act, in the initial decade following the war from 1946 to 1955. California also received between $20 and $30 million annually from the federal government in highway funds. Many of the state's two-lane highways were transformed during this period, upgraded to carry more traffic or constructed to expressway and freeway standards. The Division of Highways built bypasses around towns, created new alignments for upgraded roads, and developed new alignments for the growing system of state highways, all of which called for bridges to be designed and built. As called for in the Collier-Burns Act, the Division of Highways also designed, upgraded, and built bridges in metropolitan areas along state highways.

The Division of Highways, state and local leaders, and the motoring public became increasingly aware of the growing need for high-speed highways to connect the state's towns and cities as well as the need to improve traffic flows in and around urban areas. The two growing metropolitan centers in the San Francisco Bay area and Los Angeles were especially impacted by population growth and increased traffic congestion, and thus became the focus for much of the freeway development of this period. Freeways were also developed in California's medium and smaller-sized cities as well as along the rural coast and through the Central Valley creating ever more elaborate links between city and country. Many of the state's largest freeway projects,

[36] C.L. Hollister, "California Counties Launch Construction of 55 Bridges to Cost Approximately $5,575,000," *California Highways and Public Works*, March-April 1947, 1-8.

though, had to wait for the substantial increase in federal funding that arrived following the enactment of the Federal-Aid Highway Act of 1956.

During the late 1940s and early 1950s, the Los Angeles area experienced the state's most dramatic and recent metropolitan population growth and was at the leading edge of freeway development. The progress of freeway development during this period can be seen by comparing the total miles of completed freeway and expressway projects over time. In 1950, the Division of Highways had completed 65 miles of freeways and expressways in Los Angeles, Orange, and Ventura Counties. In 1956, 182 miles had been completed through those same counties. During this period, six major routes within the limits of Los Angeles County were developed as full freeways, with all arterial streets routed either under or over the freeway. Several more were started.[37] The first segment of the Hollywood Freeway (US101) was a three-mile section between Grand Avenue and Silver Lake Boulevard that opened to public traffic in December of 1950. Additional segments, like that shown in Figure 5, were completed by 1954.

Figure 5: Construction of the Hollywood Freeway, Los Angeles, 1951

The Pasadena Freeway (Rt. 110) first opened in 1940 as the Arroyo Seco Parkway with a six-mile unit. An additional one-half mile unit between College Street and the Hollywood Freeway was completed in 1953, connecting roadways through the four-level structure for controlled

[37] Paul O. Harding, "District VII Freeways Report," January-February 1956, 54.

traffic movement throughout the city. The Long Beach Freeway (I-710) started construction in 1951 completing 7.9 miles of the 21.5 mile project in the East Los Angeles area. Construction on the Harbor Freeway (I-110), connecting the Hollywood Freeway at the four-level interchange to the San Pedro district of the Los Angeles Harbor, did not begin until after 1951. Portions of other freeways built during this period included the Golden State, Ventura, Santa Ana, San Bernardino, Colorado, Foothill, Artesia, and Santa Ana Canyon freeways.[38]

In the San Francisco Bay metropolitan area geography and heavily populated urban areas impacted the development of a metropolitan freeway system from the late 1940s through the mid-1950s. Moving traffic across the bay from east bay residential areas to San Francisco occupational centers as well as acquiring right-of-way property required significant funding. Freeway development proceeded in segments as funding to acquire property abutting established highway alignments became available. Early disconnected segments of freeways followed an overall plan that were to be integrated into a regional system. The Bayshore Freeway, originally constructed as a highway along the bay side of the peninsula extending from the Bay Bridge to south of San Jose, began its transition to a freeway in 1947 with the construction of a short section between Burlingame and San Mateo. By 1956, the Division of Highways had completed 27.5 miles of the total 56.5 mile planned freeway. In that same year, the Division of Highways completed US-101 north of San Francisco to Santa Rosa as well as the Eastshore Freeway between the Richmond and San Jose.[39]

Elsewhere in the state from the late 1940s to the mid-1950s, the Division of Highways completed hundreds more miles of freeways. In Sacramento, for example, the Division of Highways completed the Elvas Freeway (US99E, now Business 80) and the West Sacramento Freeway (US40, portions of which are now I-80) in 1954 and the North Sacramento Freeway (US40/US99E, now I-80) in 1956. In San Diego, the Division of Highways completed the Cabrillo Freeway (US395) in 1948 and portions of US101 as freeway as the Oceanside-Carlsbad Freeway in 1953 and the Montgomery Freeway in 1955. Along the north coast of the state, segments of US101 were built to expressway and freeway standards during the early 1950s, and in the Central Valley, both north and south of Sacramento, Route 99 was rebuilt in various sections to bypass towns and accommodate larger volumes of traffic.

2.3.3. Opposition to Freeways and Their Bridge Structures

While freeways were among the factors that contributed to California's growing economy and were highly successful in moving large volumes of traffic, to many urban and architecture critics, freeways in urban areas were utilitarian slices of concrete creating psychological and physical divisions within cities and towns. A strong opposition movement against urban freeways formed in California during the 1950s. In California, and especially San Francisco, opponents protested removal of housing in areas of housing shortage. They argued that removal of lower income housing and building urban freeways hurt the poor by diverting funds away from mass transit, lowering tax revenues, and contributing to the decline of neighborhoods. Other critics of the

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[38] Harding, "District VII Freeways Report," 57-58.
[39] B. W. Booker, "Freeways in District IV: Ten Years of Modern Highway Construction" *California Highways and Public Works,* March-April, 1957, 18.

freeways included those individuals and businesses displaced by the freeways, who claimed they received inadequate compensation for their properties.[40]

Concern for the intrusiveness of urban freeway projects and their bridge structures, especially viaducts and undercrossings, became a national concern. National magazines addressed the issue. Critics included architects, politicians, property owners, and civic activists. They called elevated freeways "ugly monsters" and depressed freeways, constructed lower than the street level, "holes" in the ground. In San Francisco, prominent architects such as Robert S. Anshen and Vernon De Mars, opposed the integration of the elevated freeway into their urban environment. Citing uninspired architectural design, these critics objected to the new freeways' aesthetics. Elevated freeways and viaducts, such as the Embarcadero Freeway, blocked the financial district's view of the bay. Angry residents criticized planners, believing they relied too heavily on freeways to solve transportation problems while disregarding other transportation options. Critics also insisted that by concentrating resources on freeways, insufficient attention was paid to other problems such as slum abatement, industrial and residential growth, and community development. They considered the cost of freeways out of proportion to their benefits in comparison with education, redevelopment, health, and other programs. Furthermore, critics predicted that freeways, rather than protecting and aiding their communities, would ultimately encourage the failure of urban centers. At least one California city took action based on such criticism. In 1959, the San Francisco Board of Supervisors halted freeway construction within the city limits.[41]

The design and construction of the Embarcadero Freeway in San Francisco serves is an example of the complex nature of freeway and bridge construction in California's urban environments during this period. It is an example of how state and local officials worked successfully to build a bridge project without the complete support of the public, and it demonstrates the long term effects such a project can have on an urban setting. San Francisco's 1905 city master plan prepared by Daniel Burnham first suggested the construction of a major thoroughfare along the city's water line at the Embarcadero, though it was not constructed. The Burnham Plan shoreline project was reconsidered in 1943, but again set aside until 1947 when the city appealed to the state for a state highway to link the San Francisco-Oakland Bay Bridge and the Golden Gate Bridge. In 1952, the Embarcadero project was recognized as a future freeway with the blessings of the state and the San Francisco Chamber of Commerce. Although illustrations of the project appeared in local newspapers, residents did not appear concerned about the project. In January of 1953, the California Highway Commission held a public hearing on the project, which did not receive any negative reviews at that time.[42]

The original 1905 route was adopted by the California Highway Commission and approved by the San Francisco Board of Supervisors without public input by early 1953; its vertical plane design with two decks of four lanes each, with the lower deck carrying eastbound traffic and the

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[40] Clayton R. Giroux, "An Analysis and Evaluation of Criticism of California Urban Freeways," (M.A. Thesis, Sacramento State College, 1960), 12-43.
[41] Giroux, "California Urban Freeways," 42, 47, and 126; and Alexander Fried, "A Way Out of the Freeway Fracas," California Roadside Council, circa 1960.
[42] Giroux, "California Urban Freeways,"80-82; Herbert M. Goodwin, "California's Growing Freeway Systems," 419.

upper deck carrying westbound traffic, was to be the first of its kind in the state. The decision to build an elevated freeway rather than an underground freeway was based on cost. The vertical design reduced cost as it allowed the freeway to be narrow, eliminating additional right of way required by an eight lane freeway. Even after the first link of the freeway was constructed the project was largely free from criticism by the people and press. In March of 1955, San Francisco Recreation and Parks Commission raised the first concern as the Golden Gate freeway project was being considered. Occupants of the historic Ferry Building became vocal opponents of the project when it appeared the project would impede development of a state historic park in front of the Ferry Building. Other complaints included the possibility of blight in the area, destruction of the view, aesthetic concerns, and air/noise pollution. Every recommendation was met with a counter objection until the project reached an impasse. City officials' determined to continue with the project regardless of the objection. The impasse was resolved with opponents agreeing to beautification measures along the freeway. Construction of the Embarcadero project was suspended until the city council requested the project be moved forward in 1956. Although cost, planning, and aesthetics of the project became a concern in the local editorial pages, the viaduct section was completed in 1959, as shown in Figure 6 with additional ramps and extensions constructed in the 1960s. The issues surrounding this controversial structure were resolved only with its demolition after it was severely damaged in the 1989 Loma Prieta earthquake.[43]

Figure 6: Embarcadero Freeway, San Francisco, 1959

The controversy over the Embarcadero Freeway and San Franciscans' distaste for elevated and double-decked freeways led them to organize strong opposition to any future freeway construction. Residents and the City's Park and Recreation Commission rallied against the Western Freeway project, which would have cut through Golden Gate Park. In 1955, neighborhood organizations objected not merely to the aesthetics but to the necessity of a

[43] State of California Department of Public Works Division of Highways, "District IV Freeways," *California Highways and Public* 33 (March-April 1954): 15-16; Giroux, 83-87; Herbert M. Goodwin, "California's Growing Freeway Systems, 417-433.

freeway at all. They argued that future population growth in the area did not warrant the freeway. Current projects would provide for traffic relief, and development of a rapid transit system would alleviate any future need for freeway construction. Furthermore, residents believed that the freeway would serve through traffic rather than local traffic, reduce tax revenue by re-allocating land use, and depreciate land values. As a result of the persistent pressure of 97 resident organizations, in 1959 the Board of Supervisors canceled plans for six of nine future freeway projects, all of which would have cut through residential neighborhoods.[44] Although the mayor, state legislators and senators denounced San Francisco's Board of Supervisors for their action and threatened to withhold Federal aid funds, the Board members stood by their decision. Neighborhood associations, special interest groups, and politicians deadlocked proposed freeway projects, creating years of controversy that continued well into the 1960s.

2.3.4. San Francisco Bay Area Bridges – Postwar Additions

Of the thousands of bridges constructed during the mid-20th century throughout California, the San Francisco Bay Area received many of the state's most extraordinary structures of this period. As the city gained national and international importance, the challenges of its geographical setting required exceptional engineering achievements to help it emerge and remain one of California's most important cities. While the region had 1920s-era bridges crossing the South Bay and the Carquinez Straits, two of the city's most spectacular bridge were completed within a year of one another in the 1930s. The San Francisco / Oakland Bay Bridge opened in 1936, and the Golden Gate Bridge opened in 1937 between San Francisco and Marin County. These bridges are among the best-known in the country and were crucial to the development of the Bay Area's highway system. In the 1940s and 1950s, the Division of Highways continued to plan for, build, and upgrade highways and freeways in the Bay Area including construction of, and additions to, bridges in the region. This included several reconfigurations of the eastern approach to the San Francisco / Oakland Bay Bridge completed during this period.

The longest, and perhaps most complex San Francisco Bay Area bridge constructed during the post-World War II period was the Richmond-San Rafael Bridge that connected Marin and Contra Costa counties. After five years of construction, the bridge opened to traffic in 1956 ending a long history of ferry service connecting the two counties. A joint venture between the Judson Pacific Murphy Company and Peter Kiewit Sons' Company built the bridge. One interesting element of construction was the use of structural aluminum for falsework used for the erection of the steel trusses.[45]

Several of the area's 1920s crossings were upgraded during this time to meet the growing traffic demands. The Carquinez Strait Bridge, originally constructed in 1927, spans the Carquinez Strait and connects Solano and Contra Costa Counties. Traffic levels grew greatly across the Carquinez Strait following World War II. The Division of Highways completed a second span in

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[44] Herbert M. Goodwin, "California's Growing Freeway Systems, 439-444.

[45] "Record Span New Crossing," *California Highways and Public Works,* July/August, 1956, 1; "Aluminum Falsework" *California Highways and Public Works,* May/June, 1955, 45; and "New Bridge Crossing" *California Highways and Public Works,* November/December 1953, 1.

1958 to solve the problem.[46] The San Mateo-Hayward Bridge, crossing the South Bay between San Mateo and Alameda counties and originally completed in 1929, was largely obsolete by the 1950s. Only 35 feet in elevation, the two-lane bridge, the longest in the world when it was constructed, included a vertical lift section to allow for ship traffic. By the late 1950s, the significant increase in traffic led the Division of Highways to plan for construction of a new bridge. The new San Mateo-Hayward Bridge opened in 1967. Another South Bay span, the Dumbarton Bridge, connecting San Mateo and Alameda Counties, was also originally opened in 1927. The State of California bought the bridge from the Dumbarton Bridge Company in 1951 to insure its safe inclusion in the region's highway system. The state maintained the bridge for many decades and replaced it in 1984.[47] Although a second structure had been built across the Carquinez Strait in 1958, traffic pressure heading northeast away from San Francisco continued to grow. In response, the Division of Highways a began planning in the late 1950s for a bridge between Martinez and Benicia, which opened in 1962 replacing the last remaining state-owned ferry system in the San Francisco Bay area.[48]

2.4. Ascension to the Freeway Era: 1956 to 1959

As discussed, federal funding, which slowly increased over time, added to state highway funds to help build California's freeways and expand the state highway system in the decade following World War II. While hundreds bridges had been built along the state's roads, highways, and freeways in the late 1940s and early 1950s, the next fifteen to twenty years would prove to be the largest bridge building period in California's history. The chief impetus of this surge was the massive increase in federal funding for highway construction starting, most importantly, with the Federal-Aid Highway Act of 1956, which put into place the funding to construct the country's interstate highway system. This surge was further bolstered by the Division of Highway's freeway master plan developed in 1958. By the mid-1950s, most bridge construction in California occurred as part of freeway or highway projects, so it is not surprising that the greatest concentration of existing bridges in California built between 1956 and 1959 are in the metropolitan areas around Los Angeles and San Francisco, followed by the Sacramento region and San Bernardino / Riverside counties. There are also concentrations of bridges from this period in the areas of California that connect the state's urban centers, in the southern Central Valley, the Central Coast, and in Orange County.[49]

The state and federal governments had recognized the need for a comprehensive national highway system for defense and other needs since the late 1930s. Starting in the 1940s, the

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[46] California Department of Transportation, Historic *Highway Bridges of California*. (Sacramento: California Department of Transportation, 1990), 126; Carquinez Strait Bridge Statistics, online at http://www.structurae.de/en/structures/data/str00482.php (accessed December 9, 2002).

[47] Dumbarton Bridge online at http://www.lib.berkeley.edu/Exhibits/Bridge/dumbart.html, (accessed December 9, 2002); California *Highways and Public Works,* September/October 1951, 11; "San Mateo and Dumbarton Bridge Approach Problem, *California Highways and Public Works, November*/December 1954, 55.

[48] Martinez-Benicia Bridge online at http://www.dot.ca.gov/hq/esc/tollbridge/Ben-Mar/BMfacts.html (accessed December 9, 2002); "Benicia-Martinez Bridge Construction Starts in August," *California Highways and Public Works,* July/August 1958, 52.

[49] Los Angeles and San Francisco areas are in districts 7 and 4 respectively. Sacramento is in District 3. San Bernardino and Riverside counties are in District 8. South Central Valley is District 6, Central Coast is District 5, and Orange County is District 12.

federal government passed legislation aimed at building such a highway system. The 1941 Defense Highway Act provided funds for strategic routes, but not for a complete interstate system. Other funding for the interstate system came with the Federal Highway Act of 1944. Following the war, the federal government continued to consider transcontinental interstate road network a priority and passed the first federal aid legislation in 1954, although it did not provide enough financial support to make the complete project feasible.[50] The rapidly expanding post-World War II economy helped form an enormous and powerful set of commercial and industrial interests that supported the interstate highway system. Industries reliant on America's mobility, such as road builders, automobile manufactures, tire makers, oil and gas companies, along with automobile associations, united to promote highways with an eye on the financial benefits they would reap from development of the interstate system. During the 1950s, the auto and highway interests grew more influential in Washington D.C. The interstate highway system became a priority for the Eisenhower administration, which supported its construction for not only national security reasons, but also to enhance traffic safety and promote the country's general prosperity.[51]

The Federal-Aid Highway Act of 1956 provided funds to construct a 41,000-mile interstate system by 1972. The act increased the federal support to interstate highway construction by over 33 percent, bringing the federal contribution to nearly 92 percent of the cost. California's share of federal funding for interstate highways jumped from $9.7 million to nearly $67 million during the first fiscal year under the 1956 act. Accordingly, a record 341 miles of divided highway were added to the state system in that first year. By 1957, California had contributed 2,135 miles to the interstate system, but much remained to be built.[52] After two years of construction and review, the Federal Highway Act of 1958 provided additional funding, with California receiving $115 million for interstate system highways. The new funds represented a ten percent increase in the state's annual highway construction budget. The act further increased California's highway and bridge funding by substantially increasing the state's apportionment of the federal money. Congress abandoned its complex formula for apportionment of federal interstate funds to concentrate instead on spending in areas with the greatest need, which gave California a greater share of federal funding.[53]

In 1957, in response to the greatly increased funding from the federal government, the state legislature requested that the Division of Highways develop a plan for the state's overall highway system. The plan included how the state was going to develop its state highways as well as ways to improve city streets and county roads. The Division of Highways presented its

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[50] U.S. Department of Transportation, Federal Highway Administration, *America's Highways 1776-1976: A History of the Federal-Aid Program* (Washington, D.C.: United States Government Printing Office, 1976), 160-1; and California Department of Public Works, Division of Highways, *Tenth Annual Report*, 1957, 113. The 1954 Act provided federal funding of 66.71% for interstate construction with the state providing the 33.29% balance of the cost.

[51] Tom Lewis, *Divided Highways*, 119.

[52] California Department of Public Works, Division of Highways, *Eleventh Annual Report*, 1958, 81; and California Department of Public Works, Division of Highways, *Twelfth Annual Report to the Governor of California by the Director of Public Works*, (Sacramento: California State Printing Office, 1959), 77. Previously, only once had constructed miles of divided freeway topped 200 when 267 miles during the 1954 fiscal year.

[53] "Federal Aid: Moneys from New 1958 Act Put to Work Without Delay," *California Highways and Public Works,* May-June 1958, 46; and George T. McCoy, "California Highways…1958: An Annual Report," *California Highways and Public Works,* May-June, 1959, 46.

plan to the legislature in September 1958. The innovative master plan for the California Freeway System produced a uniform standard of roadways and bridges throughout city, county, and state jurisdictions. The plan was created with the involvement of hundreds of county and city representatives and provided for 12,241 miles of freeways, expressways, and other limited access highways, requiring the construction of hundreds of bridges. It was by far the largest freeway program undertaken by any state at that time.

Although California's landscape and built environment had already begun to dramatically change with the massive highway and bridge construction projects of the late 1930s, 1940s and early 1950s, the Federal Highway-Aid Act of 1956 set into motion an even more expansive freeway and bridge building campaign that continued into the early 1970s. The federal and state system of freeways envisioned by the master plan crossed both rural and urban areas. Each mile of freeway required, on average, twenty-four acres of land, and eighty acres for each interchange. While the freeway provided transportation of people and goods, both of which had a positive effect on the economy, removal of valuable agricultural land in the countryside and lower income housing and businesses in urban areas often had a negative economic impact. Expanded suburban development followed the freeway routes as people gained access to previously undeveloped areas. Not only were city blocks of homes and businesses demolished for freeway construction, downtown areas were depopulated of upper and middle income residents. Those who could afford to move into the larger homes and gardens of the suburbs did so at an accelerated rate. Nationwide between 1950 and 1970 the population of major cities declined while the suburban population doubled to 74 million. With the affluent families and businesses went tax revenue, which had supported city services. Although protest and criticism of freeways had begun in the 1950s, during the following decade greater discord would grow between local communities and government officials regarding the necessity, design, and routes of freeways. The public's growing response to freeway and bridge construction led to the Division of Highway's increased attention to matters of aesthetics and community planning in the 1960s.[54]

[54] Tom Lewis, *Divided Highways*, 153; Kenneth T. Jackson, *Crabgrass Frontier*, 1985, 283, 285.

3. CALIFORNIA BRIDGES 1936 TO 1959: ENGINEERING, DESIGN, AND CONSTRUCTION

The period between 1936 and 1959 was one of substantial and important change, which brought both innovation in bridge design and a vastly expanding number of bridges to California. California became a national and international leader in bridge design and construction, particularly as the state's freeway system developed. The volume of traffic as well as the speed and size of motor vehicles increased dramatically during the 1930s, 1940s, and 1950s. This led the Division of Highways and local agencies to institute and attempt many innovative and bold engineering measures to meet the demands of the state's growing and mobile population and its expanding economy. Bridge aesthetics shifted notably during this period. State and local governmental engineers became responsible for nearly all bridge design and construction around the state. The adoption of large-scale projects by the state and federal governments increased standardization of bridge design. Highway bridges from this period were part of a tidal wave of new infrastructure construction that permanently altered California's built environment and greatly enhanced its transportation capabilities.

The Division of Highways implemented many innovations during this period to enhance safety, reliability, and speed on bridges. The skew bridge, for instance, became the rule rather than the exception. Instead of bridges being located at ninety-degree angles across waterways, which created unsafe conditions and required vehicles to slow before crossing, bridges were built with as little disturbance to the road alignment as possible. Advances in materials and bridge types allowed the Division of Highways to move away from constructing through truss bridges, instead adopting mostly deck style designs. Technological advances from this period include developments in welding, concrete box girders, and prestressed concrete. New designs included innovative freeway/interchange grade separations and double-deck viaducts. The Division of Highways also began to use computers during this period. During the 1930s, it began using electronic computing machines to tabulate data. By the mid 1950s, the Division of Highways used computers for analyzing data collected in traffic surveys. Although the engineers initially distrusted the machines, reliance on the computer's capabilities grew to include using the machines to perform the "tedious calculations" necessary in bridge design, thus saving the division's engineering time. During the 1950s, when the Division of Highways experienced a shortage of engineers, it actively sought ways to shortcut the expensive drudgery of manual calculations.[55] The Division consistently cited the savings in time and money in discussions of early computer use. By the early 1960s, the bridge department used computers primarily to assist with structural calculations when designing some bridges. Computers helped the engineers achieve more accurate results, but were still extremely expensive to purchase and operate.[56]

[55] Sam Osofsky and R.K. Breece, "Automation: Machine Computations Save Engineering Time," *California Highways and Public Works*, July-August 1955, 30; California Department of Public Works, Division of Highways, *Ninth Annual Report*, 1956, 155; and George T. McCoy, "California Highways…1957: An Annual Report," *California Highways and Public Works*, January-February 1958, 34; and George T. McCoy, "California Highways…1958: An Annual Report," *California Highways and Public Works*, January-February 1959, 54.

[56] Arthur L. Elliot, "Bridge Building in an Electronic Age." Paper delivered to the WASHO conference in 1961, 253, 257; and Sam Osofsky and R.K. Breece, "Automation: Machine Computations Save Engineering Time," 30.

The following sections address various components of bridge engineering and design from the 1930s through the 1950s. The first section addresses the change in bridge aesthetics during this period. The second section discusses important designers and builders involved with constructing California's bridges at this time. The third section describes the various bridge types used during this period. These bridge type discussions are categorized by structural material and include information on the origin of the types of bridges found in California built during this period, the uses of those bridges types, and in some cases design trends during the post-1960 period.

3.1. New Aesthetics and Architecture of Bridges

By the mid-1930s, the architectural and design aesthetic for prominent new buildings and structures in California had started to shift away from the Ecole des Beaux Arts and City Beautiful Classicism of the early part of the century towards the aesthetic of the Moderne or International Modern styles that were more abstract, stripped-down, and unadorned. This trend derived from a shift of tastes away from Greco-Roman Classicism instead breaking the elements of classical architecture down to their fundamental elements of order, symmetry, and proportion to achieve the tenets of functionalism, efficiency, harmony, balance, as well as material and functional honesty. This reaction to the perceived excesses of ornament adopted during the late 19th and early 20th centuries was particularly attractive as the country emerged from the Great Depression and there was little extra money to be devoted to the aesthetics of bridges, which at the time meant adding ornamental features to utilitarian designs.[57] While many bridges across the state continued to be constructed using utilitarian designs, the Division of Highways Bridge Department emerged during this period as a national leader in the design of not only boldly engineered bridges, but also of structures with aesthetic appeal that responded to the changing visual sensibilities of professionals and the public at the time. Such spectacular aesthetic examples of this shift in taste from the 1930s include the San Francisco-Oakland Bay Bridge, the Golden Gate Bridge (27 0052), the Bixby Creek Arch (44 0019), and the Tower Bridge in Sacramento (22 0021). One need only to compare these bridges with the Classical-inspired monumental City Beautiful bridges constructed across the Los Angeles River during the 1910s and 1920, such as the Spring Street Bridge (53C0859), built 1928, or bridges such as the Lion Bridge in Modesto (38C0023), built in 1916, to understand this shift. One can also witness this transition on a more modest scale by comparing the mix of design and detail used for the bridges crossing the Arroyo Seco Parkway (53C1877 and 53 0642), completed in 1940, as shown in Figure 7, or those used for the Embarcadero and University Avenue underpasses in Palo Alto (37C0001 and 37C0005), built in 1936 and 1940 respectively, shown in Figure 8.

[57] Arthur L. Elliot, "Fifty Years of Freeway Structures," 1988, Bridges file, California Department of Transportation Library, Sacramento, 3-5 [Edited version of essay printed in *Going Places*, July-August 1989, 12-17], 2; Wilbur J. Watson, "Architectural Principles of Bridge Design," *Civil Engineering*, March 1938, 181 and 184; and Aymar Embury II, "Esthetic Design of Steel Structures," *Civil Engineering*, April 1938, 262.

Figure 7: Bridges over the Arroyo Seco Parkway, Avenue 43 (top) and Grand Avenue (bottom), 1940.

Figure 8: Embarcadero Underpass, 1936 (left) and University Avenue Underpass, 1940 (right), Palo Alto.

As in many design fields during the mid-20th century, some bridge engineers of the period sought to design structures that would not only be functional and efficient but also to represent the essence of their material, eschewing concealment and extraneous decoration for the simplicity, clean graceful lines, and expressiveness of Moderne and International Modern styles. This was expressed by the Bridge Department starting in the mid-1930s as a desire to design bridges without "archaic bric-a-brac" adornment, aiming instead for bridges whose components were "pleasingly proportioned and harmoniously arranged."[58] The Bridge Department appears to have

[58] Watson, "Architectural Principles of Bridge Design," 183; and Division of Highways, *Eleventh Biennial Report*, 1938, 54.

been influenced by the designs and concepts of Alfred Eichler who worked for the Division of Architecture in the Department of Public Works from the 1920s to the 1960s. Eichler who pointed out that not only did applied architectural elements such as moldings, cornices, brackets, and pilasters add cost to bridge design, but that it was difficult to properly apply those classical forms in bridge design resulting in typically unsuccessful compositions. The trend, thus, was away from using historical precedents in hopes that the new structures would transcend the shifts of taste from one generation to another.[59]

The evolution of bridge design accompanied the development of technological innovations such as new materials and construction methods that were less expensive and impeded less on existing roadways. Improvements included the introduction of concrete box girder, prestressed concrete, and welded steel. Designers had been cladding concrete bridges in stone or brick to not only imitate masonry bridges, but also to cover the material which at that time still tended to permit water infiltration, a problem that decreased the structural soundness of those structures. As concrete improved, there was less need for exterior cladding. Later, Moderne and Modern stylistic choices made their way into California's bridges. The introduction of concrete box girder and then prestressed concrete afforded the Division of Highways greater economy when building thousands of bridges for the post-World War II freeway system. These design types, as well as other innovations such as single column bents, were also influenced by the practice of designing skewed bridges at crossings to provide for safety and traffic demand requirements, replacing the practice of selecting simply the shortest span possible at narrow crossing points.[60]

Although aesthetics were considered in bridge design throughout the 1930s, 1940s, and 1950s, economic and safety considerations played pivotal roles in the visual effects achieved. Costs of bridge materials such as cement and steel increased modestly between the pre and post World War II periods, but the cost of labor to provide finished concrete and intricately fabricated steel girders rose dramatically. American labor costs had been steadily rising since the Progressive Era of the early 20th century, yet there was a distinct shift in labor costs during and after the Great Depression. Following World War II there was not only less unemployment than before the war, but there was decreased government subsidy for bridge labor costs as had been provided during the Depression. Industrial mass production methods, honed during war-time productions efforts, helped to offset the cost of manufactured items, but also contributed to increased homogeneity of bridge styles and aesthetics.

An example of where increased labor costs and the use of mass produced bridge components effected the aesthetics of a bridge occurred in 1949 when the Division of Highways expanded State Route 4 / US99 north from Bakersfield from two to four lanes. Bridge engineers considered several economic factors that dissuaded them from designing a structure at Oil Junction similarly to the older steel continuous bridge at that site built in 1933. The older structure had been built with a solid concrete railing and curved bottom cord girders in a modest Streamline Moderne design. The Bridge Department decided to not repeat this design because of the increased costs associated with the labor and carpenters needed to built the intricate

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[59] Leonard C. Hollister, "The Modern Highway Bridge, as Expressed by Recent Designs of the California Division of Highways," *Roads and Streets*, October 1937, 45-50.
[60] F.W. Panhorst, "Century of Bridge Progress," *California Highways and Public Works*, September-October 1950, 124.

falsework for the concrete as well as the increased fabrication and labor costs of manufacturing curved bottom chord girders. Economics thus led to a simplified design for the new bridge (50C0071, now on Knudsen Drive). To further reduce expenses, the steel girders were rolled at the mill and squared off so as to lessen the need for additional angles, plates, and skew connections. A light steel rail was installed rather than the solid concrete railing because it was less expensive to fabricate and less inexpensive to install. The aesthetic effect was the addition of a more utilitarian style bridge that lacked the same architectural character as the older structure, reflecting instead economies and the rising use of pre-manufactured components for bridges of that time.[61]

During the postwar period, the Division of Highways Bridge Department drew distinct conclusions on the appropriateness of bridge types for specific project characteristics, including assessment of the appearance of various types. In 1961, The Division of Highways' Bridge Planning and Design Manual, for example, explained that while economics was generally the "best substantiation" for bridge type selection, other considerations were to be made particularly in cases where construction costs were similar, though in its final analysis the Bridge Department extolled the utilitarian function of bridges, i.e. "convenience to traffic," above all else. Among the cost elements of bridges such as maintenance and construction time, there were also safety issues and matters of aesthetics. The safety factors included the effects of the bridge as a traffic hazard both during and after construction. Certain bridge types were also used for particular span widths. The Bridge Department judged the appearance of each type making clear preferences for bridges that were "neat and simple" and that concealed utilities and conduits, such as concrete slabs or concrete box girders. Also pleasing to Bridge Department aesthetic tastes of the time were suspension bridges, cantilevered bridges, and welded plate girders. Less desirable were concrete tee beams and riveted steel girders. Steel trusses were the least desirable design, presumed to be "not generally pleasing."[62]

Although one can clearly see a shift in aesthetics and taste in mid-20th century bridge design, many bridges constructed during this period, particularly after World War II, were designed for the greatest economy with less emphasis on the aesthetics of siting, formal expression, viewer and driver experience, or their place as civic monuments. Some of the innovations, and the economies achieved through their application, led to increased standardization of bridge design across the state and thus, in the eyes of critics, greater visual monotony. Concrete box girder and prestressed concrete bridges, for example, lent themselves to far fewer variations of form and style than had been seen in earlier bridges, and standardization of bridge design grew to meet both state and federal freeway safety standards. The result was a dual effect. Bridge standardization coincided with post-World War II aesthetic values that sought form to follow function, yet Modern design qualities were co-opted for mass production of bridges in postwar period. The Division of Highways was aware of that some of its designs had aesthetic shortcomings and began to hire architects in the 1950s to work on enhancing the visual effects of bridges. Eventually the Bridge Department created an aesthetic review section in the 1960s.

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[61] "Bridge Styles: Modern Trends in Design Influenced by Many Factors," *California Highways and Public Works*, July-August 1949, 52-55.

[62] Department of Public Works, Division of Highways Bridge Department, *Bridge Planning and Design Manual*, Vol. 2, 1955-1966, 5.7.0 – 5.7.1.14 (revised January 1961).

3.2. Engineers, Designers, and Builders

Unlike other design endeavors, bridge design and construction is often an interwoven collective effort that includes government employees, private sector contractors, and public participation. By the mid-1930s, a majority of bridge design in California had shifted to state or county employees. This shift was particularly true during World War II when most private engineers were occupied in the military or defense industries. While the Division of Highways Bridge Department designed many of California's bridges during the 1930s, 1940s, and 1950s, particularly along state routes and freeways, many local bridges were the result of county engineer involvement or counties employing consulting engineers. Steel bridge manufacturers had established common bridge truss types that could be employed in a variety of situations, and concrete designs became increasingly standardized. While each bridge was designed for its specific location and loads, many formulas and bridge types could be repeated. State or county engineers could rely on a bridge manufacturer's standard truss design. For constructing bridges, the state and counties commonly hired private contractors, many of whom worked in specific regions where they constructed a variety of bridges and other projects. Sometimes, steel bridge manufacturers would be hired to install the bridges they fabricated.

County engineers examined requirements for bridges and weighed different designs for specific uses. They then, in turn, consulted steel bridge manufacturers or state Bridge Department engineers to make final bridge design selections, often using standard bridge forms and components. For steel trusses, there were several prominent bridge manufacturers that fabricated bridges across the state. These manufacturers would construct trusses for specific installations using established truss types. Some counties did not have engineers on staff and hired consulting engineers, such as Harold B. Hammill, W.E. Emmett, or Clair A. Hill, to provide bridge design services. With expanded bridge funding from the Federal Aid Secondary Program (FAS) and the Collier-Burns Act in the 1940s, counties began taking over larger components of bridge design than they had during the 1930s. By 1947, fifteen percent of the bridges constructed under the auspices of the FAS, for example, were done by the counties themselves. This figure jumped to 44 percent by 1954.

At the state level during this period, Frederick W. Panhorst led the Division of Highways Bridge Department and exerted great influence on California bridge design in the mid-20th century. Born in Missouri, Panhorst attended the University of Illinois receiving a Bachelor of Science and Civil Engineering degree in 1915. He went to work for the Pennsylvania Railroad and other railroad companies designing bridges before doing the same for the Anaconda Mining Company designing copper smelting plants. Panhorst spent some time in the Navy at the Puget Sound Naval Yard in Bremerton, Washington and also worked for a time for the State of Washington. He came to California in the 1920s and by the early 1930s he was the acting bridge engineer for the Division of Highways. He was promoted to the position of principal bridge engineer in 1936. In 1946 Panhorst became the director of the American Society of Civil Engineers after serving in various local and state positions of the organization. With the passage of the Collier-Burns Act of 1947 and the realignment of the Division of Highways, Panhorst's title changed to Assistant State Highway Engineer, Bridges—one of the five new such positions developed. He retired in 1960. In examining the articles he wrote and paper presented to other engineers, it is clear that Panhorst was intimately involved with the bridge design and construction process of his department. It is unclear, though, on which bridges he had the greatest design influence. His name is often associated with bridges from his tenure, the most important of which was the Bixby Creek Arch completed in 1936.[63]

Of the steel bridges in California built during the 1930s, 1940s, and 1950s, the two largest bridge manufacturers were the Judson Pacific Murphy Company and the American Bridge Company. The Judson Pacific Murphy Company was a successor to several metal fabrication and construction firms that had operated in California since the 1860s. The "Pacific" part of the name came from the Pacific Rolling Mill, a San Francisco firm founded in the 1860s. The "Judson" name came from Judson Manufacturing Company, which was formed in the 1880s. The two merged in 1928 to become the Judson Pacific Company and decided to go into bridge construction, specifically metal truss bridge fabrication and construction. This entry was late in the history of truss bridge construction. Truss bridge construction had declined dramatically after World War I, and by 1928, most of the local California firms that had specialized in truss bridge construction in the late 19th and early 20th century had gone out of business. The absence of these important competitors provided a niche for Judson Pacific Company, and it responded. In 1945, Judson Pacific merged with J. Philip Murphy Corp. to become the Judson Pacific Murphy Company. This company was a general-purpose construction firm, and while it apparently devoted most of its energy toward construction of large buildings, it continued to build steel truss bridges. According to its 1946 self-published history, the company supplied the steel and iron for California's railroads, San Francisco's early cable cars, and many of the buildings of San Francisco and Oakland skylines. Judson Pacific and Judson Pacific Murphy fabricated the steel for other large scale public and private enterprises such as the intake tank towers at Boulder Dam (1936), for electric traveling cranes used by the navy during World War II, and for gold dredgers working California's riverbeds. The company also manufactured many bridges during the 1930s, 1940s, and 1950s. These included some small bridges such as the bascule style bridge on State Route 113 over the Sacramento River at Knights Landing (22 0040) built in 1933 and the Durgan Bridge in Downieville (13 0005) built in 1938 as well as medium to large scale bridges such as portions of the Golden Gate and Oakland Bay Bridges (1930s), the Highway 101 bridge over the Eel River at Scotia (04 0016R) (1941), and the Jellys Ferry Bridge (08C0043) that crossed the Sacramento River north of Red Bluff (1949). In the 1950s, Judson Pacific Murphy continued to construct bridges, and between 1957 and 1959 worked with Peter Kiewit & Sons on the Glen Canyon Dam at the Utah-Arizona border where Judson Pacific Murphy built a steel arch bridge. Judson Pacific Murphy is also noted as the company responsible for fabricating the mount for the Shane 120 inch telescope at the Lick Observatory on Mt. Hamilton, California in 1959. The firm continued into the 1960s and became the Pacific Murphy Company in 1963. With ever decreasing construction of steel trusses in the state, Pacific Murphy shifted to marine salvage and other businesses.[64]

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[63] "Two Bridge Engineers Attain Higher Rank," *California Highways and Public Works*, February 1937, 18; "F. W. Panhorst Now Director of A. S. C. E.," *California Highways and Public Works*, January-February 1946, 15; Henry Petroski, *Engineers of Dreams: Great Bridge Builders and the Spanning of America*, (New York: Knopf, 1995), 338; and "Department of Public Works-List of Officials," *California Highways and Public Works*, January-February 1948.

[64] Judson-Pacific-Murphy Company, *A Romance in Steel in California*, (San Francisco: Judson-Pacific-Murphy Company, 1946); The Kiewit Judson Pacific Murphy Company's work on the Glen Canyon Project is mentioned online at: http://www.kued.org/glencanyon/reclamation/surveyors.html (accessed August 2001). The telescope at

The American Bridge Company was originally founded in 1870 in Chicago, Illinois and operated as an independent company in the Midwest. In the late 1890s independent bridge companies began consolidating and in 1900 twenty-eight of the largest steel fabricators and constructors consolidated into the American Bridge Company, taking the name of one of the contributing companies. The following year American Bridge Company became a subsidiary of United States Steel Corporation; the corporation formed by J. P. Morgan that virtually controlled the United States steel industry. American Bridge Company remained a subsidiary of United States Steel Corporation until 1987 and is now privately owned. Because of its financial backing, immediately after consolidation in 1900 the new company commanded a great percentage of steel bridge building projects across the country and won major contracts throughout the world, using the projects to further develop the use of steel in bridge construction. In California the American Bridge Company contracted to build numerous bridge projects. Its first was a 150 foot through Pratt Bridge at Needlam Crossing over Stoney Creek in Glenn County (11C0032Z) designed by the county surveyor, and contracted and built in 1902 by the company. As steel truss construction declined during the 1930s, the American Bridge Company focused more on suspension and cantilever bridge construction. A 1941 example of their work is the bridge over the Sacramento River at Antlers in Shasta County (06 0089). This 273-foot cantilever style bridge was constructed under a contract with the United States Department of the Interior, Bureau of Reclamation and the State of California as part of the Shasta Dam and Reservoir project.

During the 1930s, 1940s, and 1950s, there were many contractors across the state that built a variety of bridge types for the Division of Highways and for counties. Information contained in the Contract Statistics from the State of California, Division of Highways Biennial and Annual Reports from the years 1936 and 1960 indicates the Division of Highways contracted with a variety of bridge construction companies, ranging from small local operations to large companies working in a multi-regional area. In the years preceding World War II the Division of Highways awarded many of the contracts to smaller, localized companies. Frequently these companies contracted for a variety of bridge types, sometimes working with other companies to complete larger projects.

An example of a company that constructed bridges both on its own and with other companies is the C. W. Caletti & Company. This company worked primarily in the Northern California through 1940. During the 1930s and 1940s, Caletti & Company contracted both for steel bridge construction and reinforced concrete construction in Mendocino, Plumas, and Humboldt counties and collaborated with the W. B. McGowan & Company, another local contractor, to complete contracts for steel bridges in Plumas County in the mid-1930s.

The Division of Highways also awarded contracts to companies working regionally in California. An example of a company completing contracts for various kinds of bridges and working in a mid-state region is the E. T. Lesure Company. This company completed contracts for steel, timber, and reinforced concrete bridges in an area ranging from Sierra County to Monterey County between 1935 and 1940.

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the Lick Observatory is in a list compiled by John M. Hill, Steward Observatory, University of Arizona, March 22, 2001. The list is online at: http://abell.as.arizona.edu/~hill/list/bigtel99.htm (accessed August 2001).

After World War II many companies expanded their contract area and began collaborations with multiple companies on various projects. While localized companies continued to operate in the postwar era, a significant number of bridge construction companies sought and were awarded contracts throughout the state. Parish Brothers is an example of a company that continued to work independently while branching out into collaborating with other companies to fill bridge contracts. Although fairly localized before the war undertaking contracts in the Imperial County area, Parish Brothers expanded into Yuba, Butte and Sonoma counties in the 1950s with collaborating with companies such as Carl N. Swenson Company and Engineers Ltd. Similarly, Dan Caputo Company completed contracts starting in 1939 and extending into the 1950s by collaborating with Ed Kebbler Company. The two joined together to complete concrete bridge projects in San Francisco Bay area between 1939 and 1954. After the war and into the 1950s Caputo completed similar construction contracts as an individual company in the Central Coast counties of Santa Barbara, San Luis Obispo and Monterey, with others in Sacramento County.

Frederickson Brothers, a company completing contracts throughout the period examined, further illustrates the diversity with which bridge construction companies operated. Between 1936 and 1959, Frederickson Brothers collaborated with the Heafey-Moore Company, Watson Construction, Westbrook, Kasler and M&K on numerous bridge projects throughout the state. In prewar years, Frederickson Brothers combine with Heafey-Moore Company and Watson Construction Company on projects located in Sutter and Sonoma Counties, for example. In postwar years Frederickson Brothers expanded their area to include projects in Shasta and Los Angeles counties.

The Guy F. Atkinson Company is an example of a California company that began as a family owned construction company concentrating in heavy earthmoving and concrete projects that grew into one of the world's largest diversified construction and manufacturing companies. Founder Guy F. Atkinson, born in 1875, was the youngest of six sons in the family of George W. Atkinson of Pennsylvania. The senior Atkinson operated the G. W. Atkinson and Sons Construction Company in Pennsylvania. In the 1890s, he moved his family and business to Colorado Springs, Colorado where Guy began his professional career in the family business. By the time he was twenty-one, Guy F. had become a full partner. As general building contractors, the company specialized in constructing schools, courthouses, and hotel buildings. In 1910 Guy F. relocated to California where he established his own firm and shifted his attention to building roads, tunnels, and infrastructure, usually working with one or more of his brothers, primarily in the Los Angeles area. While the company concentrated on road building, projects like the Pardee Dam on the Mokulumne River built in the 1920s were forerunners to large construction projects that later defined the company and its place in engineering history in the western states. Continuing the tradition of a family business, the Guy F. Atkinson Company incorporated in 1934, formed by Guy and his two children, George Atkinson and Elizabeth Whitsett. The company's California offices were located in San Francisco, and the company continued contracting both large and small projects, building their reputation on the west coast. In the early 1930s, the Guy F. Atkinson Company joined with the Silas Mason Company of New York; the Walsh Construction Company of Davenport, Iowa; and the Kier Construction Company of Los Angeles to form a new combine known as MWAK. MWAK won the contract to excavate the dam abutments, divert the river and construct the foundations and lower half of the Grand Coulee

Dam on the Columbia River. During the 1930s the company continued with local road projects in Southern California as demonstrated by the San Gabriel Highline Road in 1933 and the Angeles Crest Forest Highway in 1936.[65] United States entry into World War II refocused company projects to building defense facilities throughout the west coast. Defense facilities like Terminal Island (later Long Beach Naval Base) represented the company's World War II activities. During the war the Guy F. Atkinson Company agreed to manage production at the Willamette Iron and Steel Corporation (WISCO) in Portland, Oregon, which constructed over 300 ships. This experience was the beginning of the company's postwar diversification into several areas outside of heavy construction.

In the postwar world, the Guy F. Atkinson Company expanded their organization to pursue contracts for building and rebuilding infrastructure throughout the world, contributing in the construction of a bridge at Gorgopotamus, Greece in 1947; the Sakuma Dam in Japan, their first major hydroelectric project; and miles of road reconstruction throughout Europe. The company contracted to work on numerous road and bridge projects throughout California during this period. Representative examples include the Fort Bragg Highway and Bridge built in 1947 (10 0176); reconstruction of the Tehachapi Highway and several highway bridges in the late 1940s; the Mendocino highway in Ukiah; and the Bayshore Freeway in the 1950s.[66] Over the next several decades the company continued to diversify and expand their interests and operations and are recognized today for their expertise in large dam and hydroelectric projects, as well as for roadwork and bridge building projects.[67]

3.3. Bridge Types

California's bridges built between 1936 and 1959 were constructed in steel, concrete, and timber. There was an increased use of continuous concrete and continuous steel for bridges during this period, innovations in welded steel, and the introduction of concrete box girders and prestressed concrete. Despite the increased availability of materials and improved transportation capacities that allowed steel and concrete bridges to be built virtually anywhere, the Division of Highways and local agencies still found it efficient to build timber bridges as well.

3.3.1. Steel

While concrete came to clearly dominate bridge construction in California during the 1930s through the 1950s, steel was still used in great volumes. Of those structures built between 1936 and 1959, steel and continuous steel girder bridges are the second most prolific type of extant bridge in the state. Only concrete and continuous concrete slab types are more abundant. As traffic demands required wider roads and taller vertical clearances, construction of steel bridges steadily decreased in California. Approximately one third of the new bridges constructed in the state during the late 1930s were steel. By the 1950s that number dropped to around 20 percent,

[65] Atkinson, Ray N., *Guy F. Atkinson Company of California: A Free Enterprise Success Story*, (New York: Newcomen Society of the United States, 1985), 8-9.
[66] Guy F. Atkinson Company of California, *Guy F. Atkinson Company, Contractors, Engineers: Skill, Integrity, Responsibility*, (South San Francisco, CA: Guy F. Atkinson Company, 1948), section VII.
[67] Atkinson, Ray N., *Guy F. Atkinson Company of California*, 16-17.

and by the early 1970s steel bridges accounted for less than ten percent of new bridges constructed in the state. Of the steel bridges constructed during this period, continuous steel, where members are longer than simple girders and supported in more than two places, was increasingly used. Continuous girders provide greater rigidity to both girder and truss bridge designs. Continuous steel girder bridges first became common in the United States around the turn of the twentieth century for rapid transit and highway bridges, with some examples still standing in California built between 1900 and 1930.[68] Prior to World War I, though, continuous steel structures were limited to girder bridges and short-span trusses. This changed after 1917, when engineer Gustav Lindenthal completed the Ohio River Bridge at Sciotoville, Ohio, which featured two parallel continuous trusses. Although early examples of the continuous steel girder suffered from some disadvantages, including stress induced by pier settlement and other dangerous secondary stresses, its use increased as steel quality improved. Continuous steel was found to be more rigid than simple steel members as it was found to work as a single unit, thereby distributing loads throughout and decreasing the load on any one portion of the structure.[69]

The most important innovation in steel bridge construction during the 1930s through the 1950s was welding. Welding, or electric arc-welding, was originally invented in the 1880s by French inventor Auguste de Meritens, but was not used in building construction until the early 20th century. Welding was used for sporadic purposes and in some building projects in the United States during the 1920s and appears to have been first used on California bridges during the 1930s. By the late 1930s, state engineers were studying and experimenting with welding to improve techniques and applications. Welded bridges promised to be lighter and easier to construct than riveted structures because they did not require rivets, tie plates, and lacing bars, and they could be constructed on the ground and moved into place. Welded truss and girder bridges also promised to provide cost savings by decreasing the volume of metal necessary. Implementing use of welding in bridge construction, however, required investment in welding equipment plus skilled designers and welders. Proponents not only considered welding economically viable, but they also claimed there would be aesthetic advantages to constructing such bridges. Welding was not used widely as a cutting edge construction method in the 1930s, in part because of the limited bridge construction of the Depression-era. There were difficulties externally inspecting it for defects and early welding techniques were, at times, structurally weak.[70]

During the 1930s through the 1950s, welding on bridges was mostly used for joining specific portions of structures or was used for making repairs onsite. Welding was not restricted solely to girder structures, but was also used on truss and movable bridges. For example, the Division of Highways welded the plates for the girders on the South Redding Underpass (06 0013) on State Route 273 when the structure was constructed in 1938. The lower chord of the Rio Vista lift span bridge (23 0024), built in 1944, was also welded. Only a few bridges were constructed with all welded designs prior to World War II, such as the Bradley Overhead in Merced County (39

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[68] Carl W. Condit, *American Building: Materials and Techniques from the Beginning of the Colonial Settlements to the Present*, 2nd Ed., (Chicago: University of Chicago Press, 1982), 126.
[69] Carl W. Condit, *American Building: Materials and Techniques*, 215-216.
[70] Carl W. Condit, *American Building: Materials and Techniques*, 192-193; and "Three State Engineers Win Awards in Welding Design Competition," *California Highways and Public Works*, November 1938, 16, 17, and 28.

0044), built in 1931, and the San Juan Creek Bridge in San Luis Obispo County (49 0028), built in 1941. In the 1950s, entire welded structures became much more common as construction practices were perfected and the safety of welded bridges was recognized. Welding was boosted into a more prominent role in bridge construction during the early 1950s when the federal government limited the use of rolled steel in bridges during war restrictions for the Korean conflict. With fewer large rolled steel members available, the Division of Highways used welding to build up structural elements of large bridge projects. By the mid-1950s, the Division of Highways regularly constructed large all-welded structures, such as the viaduct for the elevated Bayshore Freeway in San Francisco, shown in Figure 9, which won an American Institute of Steel Construction award in 1954.[71]

Figure 9: Bayshore Freeway Viaduct under construction, San Francisco, 1954.

3.3.1.1. Steel Girder and Girder / Floorbeam

Girders are among the most basic means of constructing bridges. During the 1930s through the 1950s the horizontal support member spans were built in a variety of ways and to various lengths depending on the composition of the steel and the manner in which it was fabricated. Girders

[71] H.D. Stover to F.W. Panhorst, letter regarding welding processes reports and list of welded bridges in California, November 2, 1944, Structures Maintenance Historical Collection, General Information File, California Department of Transportation Library, Sacramento; and Division of Highways, *Sixth Annual Report*, 1953, 157. The award winning section of the Bayshore Freeway was at the 9th and 10th Street Viaducts, now considered part of the Central Viaduct in San Francisco.

required little or no falsework during construction and were delivered on site ready for assembly. Girder bridges from this period include I beams, rolled beams, and plate girders. Girders were built in both simple and continuous spans.[72] Rivets had replaced steel pin connections between girders and other support members during the early 20th century. Welding, in turn, began to replace rivets to connect steel bridge components during this period. Steel girders remained costly to maintain though as they required painting, particularly when they were located coastal areas.

As stated, steel girder bridges are among the most abundant type of bridges in the state built between 1936 and 1959. They are represented throughout the state; the largest concentrations are in urban areas around Los Angeles and San Francisco. There are also concentrations of steel girder bridges from this period at the north and northeast portion of the state as well along the Central Coast. The counties with the fewest steel girder bridges built between 1936 and 1959 are San Diego, Imperial, and Orange counties.

3.3.1.2. Steel Trusses

Steel truss bridges were built in great numbers on California roads and highways starting in the late 19th century. After the end of World War I, newer materials and designs, especially concrete arches and girders, began to replace truss bridges.[73] In the 1930s, 1940s, and 1950s, steel trusses continued to play an important role in bridge construction in California, particularly in Northern California. Of the steel truss bridges remaining in the state from this period, the most common truss type is the Warren truss. This is followed by the Pratt truss and its variables such as the Parker Truss, Camel Back, and a few Pennsylvania Petit and Baltimore Petit. The other notable truss type used during this period, as describe below, was the Bailey truss, a type developed by the military during World War II. The greatest concentration of existing steel truss bridges built between 1936 and 1959 are in northern portion of the state. This is followed by the San Francisco Bay area, the northern coast, and around Sacramento. Fewer metal trusses were constructed in the southern part of the state along the Central Coast, the southern Central Valley, and the Los Angeles region. No metal trusses from this period exist in Mono, Inyo, San Diego, Imperial, and Orange counties. The distribution of existing metal truss bridges in California indicate a concentration of this bridge type in Northern California where, in some rugged counties, access to concrete plants and equipment may have been difficult and where it would have been more economical to ship dismantled metal trusses to assembly sites in rural or mountainous areas.

The following sections provide brief historical backgrounds to each truss type built between 1936 and 1959 and which are still represented among the existing bridges found in California today. In general, truss bridges are classified by the position of the deck, or roadway, in relation to the trusses. Through truss bridges carry the deck on the lower chord, or support, with lateral supports overhead. The through truss configuration were used for large structures with long spans, but because they were closed overhead, the vertical clearance was restrictive. A variation

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[72] Simple girders are supported a each end, where as continuous girders are usually longer than simple girders and are supported with more than two supports. Continuous girders provide greater rigidity to both girder and truss bridge designs.

[73] Carl W. Condit, *American Building Art: The 20th Century*, (New York: Oxford University Press, 1961), 207-211.

on the through bridge is the pony truss bridge which carries the deck on the lower chord, but has no lateral overhead supports. Pony trusses were more commonly used for smaller bridges with short spans. Deck truss bridges carry the roadway on the top chord with the truss extending below the deck level. Deck trusses were increasingly used during this period, as they could be built to carry greater loads and there were no vertical clearance issues.

Warren Truss

Patented in 1848 by two British engineers, the Warren truss type was first used in the United States in 1849. The simplest of all truss forms designed at that time, the Warren truss featured diagonals alternately sloped in opposite directions. This triangular outline makes the Warren truss one of the most easily recognizable. The Warren truss became popular in the United States at the end of the 19th century, but in a form that utilized vertical posts and single diagonals.[74] The Warren trusses came into common use on California highways during the 1920s and 1930s. Most Warren trusses found in California are pony trusses with the later variations in the 1940s through the 1950s commonly including both vertical supports and polygonal top chords. Approximately three quarters of the Warren truss bridges built during this period are located in Northern California, the greatest concentration of which are in Tehama and Plumas counties.[75]

Pratt Truss (including Baltimore Petit, Camelback, Parker, and Pennsylvania Petit)

Historian Carl Condit called the Pratt the "first scientifically designed truss."[76] It was invented by Thomas Pratt, a Boston-born architect-engineer, and Caleb Pratt, his father. Thomas Pratt was active in bridge design from the 1830s through the mid-1870s. He patented the Pratt truss form in 1844, describing the design as useful in wood and iron, or in iron alone. The truss was distinctive in that it included vertical compression members and diagonal tension members. As Thomas Pratt had foreseen, this form was especially adaptable to the all-metal bridges that were built in the United States in large numbers after the end of the Civil War. It is likely that many thousands of all-metal Pratt truss bridges were constructed in the United States, first in iron and later in steel. In time, variations developed building upon the basic Pratt design, but with improvements to facilitate longer spans and greater loads. These variations were also given proper names, reflecting their inventor or place of origin. The three most important variations on the Pratt truss were the Parker truss, the Pennsylvania Petit, and the Baltimore Petit design.[77] Railroad companies erected Pratt truss bridges in great numbers, but this bridge type was also used on many highways during the late 19th and early 20th century when improved hard surface roadways expanded through rural areas linking towns and enhancing access to remote areas.

The Parker truss, developed by C.H. Parker, is simply a Pratt truss with a polygonal top chord. Stronger than a regular Pratt truss due to its arched top chord, the Parker truss' irregularly sized pieces made it more expensive to construct. Similarly, the camelback truss is a variation on the

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[74] Carl W. Condit, *American Building: Materials and Techniques*, 100.

[75] California Department of Transportation, *Historic Highway Bridges of California*, 46; and T. Allan Comp and Donald Jackson, *Bridge Truss Types: A Guide to Dating and Identifying*, (American Association for State and Local History Technical Leaflet 95, History News, Vol. 32, No. 5, May 1977), n.p..

[76] Carl W. Condit, *American Building Art: The 19th Century*, 109.

[77] T. Allan Comp and Donald Jackson, *Bridge Truss Types*, n.p. For more information on truss types, see Bruce S. Cridlebaugh, "Bridge Basics," online at: http://pghbridges.com/basics.htm (accessed on November 21, 2002).

Parker truss, as its arched top is formed by five slopes rather than a single or multiple arched top chord. The camelback's design was popular across the United States because of its economical cost and improved stress distribution.[78]

In the 1870s, as trains began to carry larger and heavier loads, engineers devised variations on the Pratt truss which enabled them to span longer distances and carry greater loads. Railroads took advantage of a new truss that utilized sub-struts and sub-ties to provide additional support. The Baltimore and Ohio Railroad initially built several of this new form, which earned it the name "Baltimore Petit," in 1871. In 1875, the Pennsylvania Railroad added an arched top chord and called its version the "Pennsylvania Petit." Other railroad lines gradually adopted these two styles, and later these truss types were adapted for highway use.[79]

Bailey and other Military Surplus Bridges

The Bailey truss bridge, also known as the Army truss, was first used for military efforts during World War II. Sir Donald Bailey, of Great Britain's Royal Engineers, designed the Bailey truss in 1940 to the support new generation of tanks, which weighed up to 35 tons. By the war's end, the army had manufactured hundreds of miles of Bailey bridges, many remaining unused following hostilities. Surplus Bailey trusses became available after the war. The truss proved its usefulness and was put into civilian production.

Figure 10: Temporary Bailey Truss on Eggo Way at Silver Creek, San Jose, January 2003 (JRP Historical Consulting Services).

The popularity of this truss after World War II came from its interchangeable pre-fabricated steel components and its versatility. Bailey bridges could be assembled in seven different configurations up to three panels wide and two panels stacked on top of one another, each referred to as a "story." Successive set of panels increased the structural strength of the bridge. The need for multiple panels became necessary because as the length of the span increased the load capabilities decreased. A single story, single truss Bailey bridge could span ninety feet, and

[78] T. Allan Comp and Donald Jackson, *Bridge Truss Types*, n.p.
[79] T. Allan Comp and Donald Jackson, *Bridge Truss Types*, n.p.; California Department of Transportation, *Historic Highway Bridges of California*, 45; and Carl W. Condit, *American Building: Materials and Techniques*, 143.

safely carry 16 tons. Adding another truss to the bridge both increased the span length and allowable tonnage, so that a single story, triple truss bridge featured a 150 foot span and handled up to 18 tons. Additionally, a double story, double truss could handle a 160 foot span, but only 23 tons, while a double story, triple truss bridge could extend 160 feet but handled 35 tons.[80] Bailey truss bridges were immediately adopted for use along California roads, even prior to the war's end. These bridges appear to have all been built along local roads, in rural or suburban areas. Baileys proved to be easily adaptable to many environments and were sometimes used to quickly replace older structures or used as temporary structures. As shown in Figure 10, this temporary use continues today.

In addition to the Bailey truss, counties and the Division of Highways took advantage of other, low cost, surplus United States Army portable steel highway bridges following World War II. For example, the Mill Crossing Bridge (10P0002) was completed in 1947 on a service road across Lagunitas Creek in Samuel P. Taylor State Park in Marin County. The structure was an Army surplus steel box girder with a wood deck that featured angles welded to subdivided Warren trusses. Because Army bridges did not have railings, the Division of Highways added steel railings to the structure. Another Army surplus bridge was built in 1947 in Pfeiffer Redwood State Park in Big Sur (44P0001). This bridge over the Big Sur River consisted of two parallel Army bridges, each 125 feet long, with double Warren trusses. The state added a timber railing to this structure as well.

Cantilever

With the exception of minor bridges on rural roads, cantilever truss bridges were first constructed in the United States following the Civil War. In 1867, the C.P. Parker designed an iron-truss cantilever bridge for the Solid Lever Bridge Company of Boston. Railroads soon adopted the form. The first railroad cantilever bridge in the United States was built in Kentucky in 1877, and the design gained popularity during the last decades of the nineteenth century. Cantilever bridges provide a distinct advantage by permitting a long uninterrupted span created by the two opposing trusses meeting without a center support. A prominent example of this type is the Carquinez Straits Bridge (23 0015L), built in 1927, which was the first large highway bridge built using a cantilever truss in the United States. The Division of Highways added a second cantilevered bridge at this location in 1958.[81]

Cantilever bridges continued to be built, albeit somewhat infrequently, in California during the late 1930s, 1940s, and 1950s. The Division of Highways used cantilever bridges for some of the state's largest bridges of the period, including the 1956 Richmond-San Rafael Bridge (28 0100) and the East Carquinez Bridge (23 0015R) built in 1958, both of which are through cantilever trusses. Large deck varieties erected during this period include the Pit River Bridge (06 0021)

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[80] Australia Defence Army, Royal Australian Engineers, "History of the Bailey Bridge," online at: http://www.defence.gov.au/army/RAE/History/Bailey_Bridge.htm, (accessed November 7, 2002); and Bailey Bridge Equipment Company, "Panel Bridge, Bailey Type, M1," Structures Maintenance Historical Collection, General Information File, File 3802, California Department of Transportation Library, Sacramento.

[81] Carl W. Condit, *American Building: Materials and Techniques*, 57, 144, 146, 219; California Department of Transportation, *Historic Highway Bridges of California*, 128.

across Lake Shasta along Interstate 5 (1940, widened in 1964) and the cantilever bridge along Route 1 across Noyo Harbor at Fort Bragg (10 0176) from 1948.

Vierendeel

Developed in 1896 by Belgian engineer Arthur Vierendeel, the Vierendeel truss is characterized by the absence of diagonals. Historian Carl Condit refers to the Vierendeel truss style as "radically different from any of the triangulated forms."[82] The truss replaces the diagonal rods with stiff vertical members, giving it a distinctive look. The Army Corps of Engineers first used the truss type in the United States in Glendale, California on city streets over a flood control channel in 1937. The Vierendeel truss never became popular in the state or the nation. The three Glendale Vierendeel trusses are unique among California bridges and are likely among the only bridges of their type in the United States.[83]

K-truss

American engineer Stephen H. Long developed the K-truss style bridge using the bottom frame of a truss bridge he patented in 1830. Long's truss featured two short diagonal rods which were less susceptible to buckling than other bridge types. The truss type appears not to have been used in the North America until after Ralph Modjeski designed the Canadian K-truss style bridge over the St. Lawrence River at Quebec, built between 1911 and 1917. N.E. Lant utilized the K-truss form in a highway bridge in Louisiana in 1933, and the truss is commonly used in the United States within the structure of steel arch bridges. The K-truss is rarer, however, as a main supporting structure. K truss is a rigid design, but requires more material and is more complex to build than other truss types, which may be why there are not more of them in California. One of the first California examples, and the only example remaining in the Caltrans bridge system, is the Tobin Bridge (09 0004) on the Feather River Highway in Plumas County. Completed in 1936 by the California Division of Highways, the Tobin Bridge's north abutment is located directly beneath a truss bridge carrying the tracks of the Western Pacific Railroad. At least one other K-truss bridge was built in California. It was built on US101 over the South Fork of the Eel River in Humboldt County near Dyerville in the late 1930s. It was bypassed in the late 1950s with a steel girder bridge.[84]

3.3.1.3. Steel Arch

There is only one steel arch bridge within the Caltrans bridge system built between 1936 and 1959. It is located on the South Fork of the Smith River in Del Norte County within the boundaries of the Six Rivers National Forest. The George E. Tyron Bridge (01C0005), was designed by consulting engineer Clarence E. Seage and built by the Underground Construction Company in 1948. Very few steel arch highway bridges have been built in California, and not

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[82] Carl W. Condit, *American Building: Materials and Techniques,* 224.
[83] Carl W. Condit, *American Building: Materials and Techniques,* 225; and California Department of Transportation, *Historic Highway Bridges of California*, 68.
[84] Carl W. Condit, *American Building: Materials and Techniques,* 224; and Division of Highways, *Tenth Biennial Report*, 1936, p. 83.

many remain. There are only five built in or before 1935 and seven built since 1960 within the Caltrans bridge system statewide.

3.3.1.4. Suspension

Suspension bridges are among the most dramatic and aesthetically pleasing transportation structures, but the Division of Highways has designed and constructed very few of these bridges. There are eleven in the state, only four of which were constructed between 1936 and 1959. Of all bridge types, this one was likely the most costly and time consuming to design and construct. It required greater levels of maintenance than other steel bridges, was not designed to travel over traffic, required special towers, anchors, and guide wires not used in other designs, and was impossible to widen. The design's greatest assets were that it could be used for very long spans, and its construction required no falsework. In addition to the cost of building suspension bridges, the disaster of the Tacoma Narrows Bridge at Puget Sound in Washington was also likely responsible for dissuading California engineers from building this bridge type. In November 1940, the 2,800 clear span of the Tacoma Narrows Bridge began to corkscrew uncontrollably in heavy winds and snapped due to insufficient stiffening girders placed in the 39-foot wide structure. Although no lives were lost, the accident was a watershed for suspension bridge design that brought careful reconsideration regarding the aerodynamic qualities of this bridge type.[85]

California's two greatest bridges include suspension spans, the Oakland Bay Bridge (1936) which included two back-to-back suspension bridges and the Golden Gate Bridge (1937). Only two other suspension bridges built between 1936 and 1959 remain within the Caltrans bridge system. They are Canyon Creek Road over Scott River in Siskiyou County (02C0049), completed in 1938, and Mosquito Road over South Fork of the American River in El Dorado County (25C0061), completed in 1939. The next suspension bridges in California were constructed in the 1960s, including the Vincent Thomas Bridge in Los Angeles (52 1471), completed in 1963. The Division of Highways completed a suspension bridge over the Klamath River near Orleans in September 1940, but it was destroyed by a flood in 1964. The Klamath River Bridge was replaced in 1966 (now bridge 04 0069). The Bridge Department chose a suspension span for this section of State Route 96 because the streambed could not support the appropriate piles for the falsework that would have been needed for a reinforced concrete bridge, and a cantilever type structure was found to be more expensive in this case.[86]

3.3.1.5. Moveable: Swing, Lift, and Bascule

Into the mid-20th century, movable bridges continued to be constructed to carry vehicular traffic on highways over navigable waterways, separating highway / roadway and waterway traffic. There were three types of movable bridges built. Swing bridges were constructed with a central pivot. Lift bridges were constructed with a central span that could be raised, and bascule, or

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[85] Department of Public Works, Division of Highways Bridge Department, *Bridge Planning and Design Manual*, Vol. 2, 1955-1966, (revised January 1961), n.p.; and H.J. Hopkins, *A Span of Bridges: An Illustrated History*, (New York: Praeger Publishers, 1970), 230-232.

[86] "Orleans Bridge Wins First Prize in National Design Competition," *California Highways and Public Works*, June 1941, 2, 3, and 21.

draw, bridges were constructed with one or two leafs that could be raised vertically from an abutment to permitted passage through the waterway. Fifteen movable roadway bridges built between 1936 and 1959 remain in California on the Caltrans bridge system. As with all movable bridges in the state, a majority of the structures from this period are located in the Sacramento-San Joaquin Delta on navigable channels. Elsewhere, two moveable bridges span the channel between Oakland and Alameda in Alameda County, one is located over the Napa River in Napa, one spans the Cerritos Channel in Los Angeles County, and one can be found along the upper Sacramento River in Glenn County.

Swing

Swing bridge types are the oldest movable bridge types and were first constructed in California in the nineteenth century, although the oldest remaining example is the Bacon Island Bridge, built in 1906 and relocated in 1950. Symmetrical in design, swing bridges pivot from a central pier. Popular in the nineteenth century because they were relatively easy to construct, swing bridges fell out of favor by the early twentieth century due to several disadvantages: they operated slowly and had to be fully opened to allow vessels through; more importantly, they required a central pier in the center of a navigation channel. By the 1920s, California engineers favored bascule type bridges, yet continued to build some swing bridges.[87] Of the fifteen remaining moveable bridges in California built between 1936 and 1959, seven are swing bridges. Of these, six are located in the Sacramento – San Joaquin delta, and one crosses the Sacramento River on State Highway 162 in rural Glenn County.

Lift

Although small vertical lift bridges were constructed in Europe in the early nineteenth century, the first large vertical lift bridge built in the United States was the South Halstead Street Bridge in Chicago in 1892. Vertical lift bridges were slow to gain popularity, but early 20th century improvements in design allowed for the construction of many lift bridges nationally. Unlike a swing bridge, a lift bridge lacks a central pier and consists of two large towers flanking the movable span and supporting the machinery that lifts the deck. Although the lift bridge is more expensive to construct and maintain than swing bridges when built with a short span and high lift, it is more economical and more widely used for long spans and low lifts.[88] Few lift bridges have been built in California. Perhaps the most famous is the Tower Bridge (22 0021), linking Sacramento and Yolo counties. Built between 1934 and 1936 in the Streamline Moderne style, the Tower Bridge features unique parallel tower legs, adding to the vertical effect, and a steel through Warren truss.[89] Four lift bridges built during the period 1936 to 1959 remain on California highways, all built between 1944 and 1949. Located in Napa, Solano, Los Angeles, and Sacramento counties, these four lift bridges are all constructed of steel and are through trusses. An important example is the Commodore Schuyler F. Heim Lift Bridge in Long Beach (53 2018), spans the Cerritos Channel connecting the ports of Los Angeles and Long Beach with Terminal Island. Its location between two of the west coast's busiest ports necessitated a long

[87] California Department of Transportation, *Historic Highway Bridges of California*, 111.
[88] George Hool, et al, *Moveable and Long-Span Steel Bridges*, (New York: McGraw-Hill Book Company, Inc., 1943), 158-160.
[89] California Department of Transportation, *Historic Highway Bridges of California*, 120.

central span; its 240 foot vertical lift through truss is raised by two 400 ton counterweights to an elevation 175 feet above the water when fully open.

Bascule (Drawbridge)

Early forms of bascule bridges were first constructed in Europe during the first half of the nineteenth century, but modern bascules were not developed until the 1880s. In the United States, the first bascule bridges were constructed in Chicago in 1893. They gained popularity in California in the early twentieth century as they solved many of the disadvantages that the earlier type of moveable bridge, the swing bridge, faced. Bascule bridges feature a hinge, or a trunnion, which pull the moveable span upward and inward, thereby allowing vessels to pass through an unobstructed waterway. Bascules were preferred over swing types as they could be only partially raised to allow smaller boats through, thereby speeding the process. Unlike swing bridges, bascules did not need a central pier, which obstructed the shipping channel.[90]

The Strauss Bascule Bridge Company, under the direction of Joseph B. Strauss, built the majority of California's bascule bridges. Strauss, a Chicago-based engineer who maintained a California office, eventually relocating there in the 1920s, is best known for designing the Golden Gate Bridge. His "Heel Trunnion Bascule" design features concrete counterweights that reduced the power needed to lift the leaf, or movable span. Four trunnions ensure that the counterweights are balanced.[91]

By the middle of the twentieth century, moveable bridges fell out of favor as engineers opted to construct high, fixed span crossings. In recent decades, the state began to remove its moveable bridges and replace them with fixed spans, eliminating the cost of staffing and maintaining them.[92] As a result, only four bascule bridges built during the period 1936 to 1959 remain, two on California highways and two on secondary county roads. Two of these are located in Alameda County (33C0026, 33 0086), and one each in Sacramento and San Joaquin counties (24C0005, 29 0016F respectively).[93]

3.3.2. Reinforced Concrete

Reinforced concrete was increasingly used for bridges in California from the 1910s onward. Construction of concrete structures with steel embedded rods, first invented for building construction in warehouses, for example, had proved to be an extremely effective means of improving concrete's natural tensile weakness. While concrete was recognized for its strength when placed in compression, without steel support concrete tended to crack when placed in tension, such as when it was bent. Reinforced concrete was thus greatly beneficial in bridge construction, which required increasingly higher load capacities as motor vehicle use increased during the early 20th century. By the mid-1930s, reinforced concrete bridges accounted for a

[90] George Hool, et al., *Moveable and Long-Span Steel Bridges*, 24.
[91] California Department of Transportation, *Historic Highway Bridges of California*, 112.
[92] California Department of Transportation, *Historic Highway Bridges of California*, 112.
[93] There is at least one bascule bridge that is no longer operable and is currently categorized as a through truss bridge. This is Bridge 29-0016F, over the San Joaquin River at Mossdale, San Joaquin County, built in 1949.

majority of new bridges that the Division of Highways and local agencies constructed in California. Besides its use in arches, reinforced concrete (and later prestressed concrete, discussed below) was built into bridges in the form of slabs, tee beams, and girders. Figure 11 shows cross sections of the concrete bridge types built during this period.

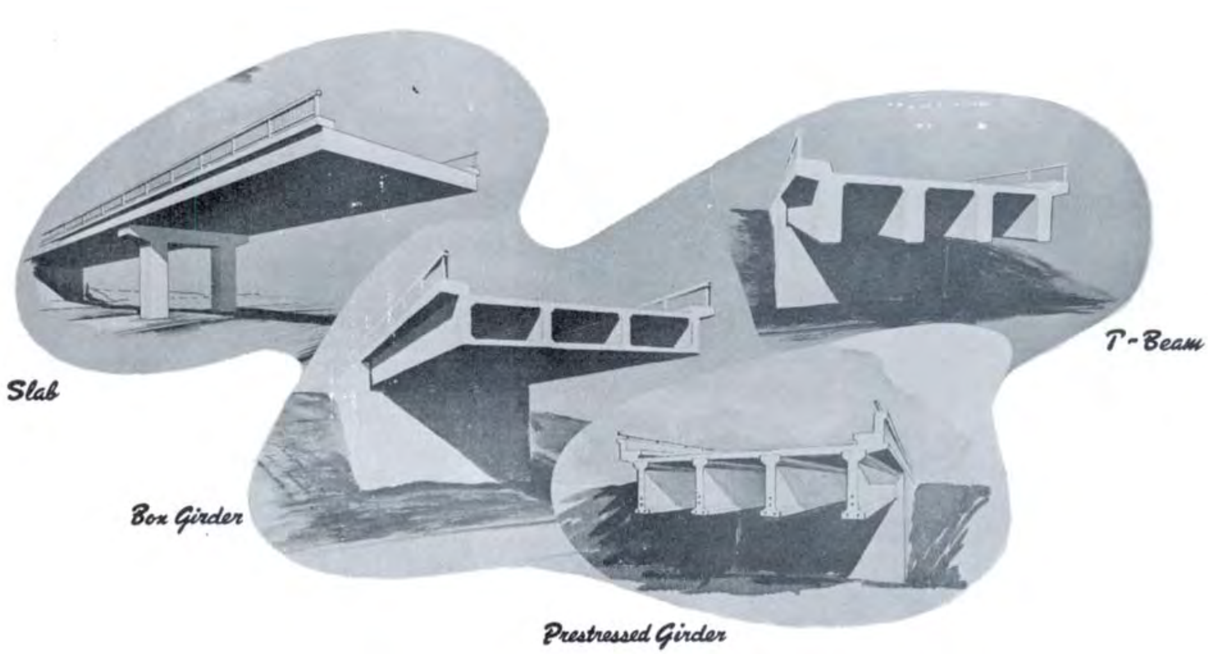

Figure 11: Concrete Bridge Types, Division of Highways Bridge Planning and Design Manual, September 1958.

Slabs are rigid monolithic horizontal elements on which the roadway directly sits. Concrete tee beams (or T-beams) are concrete girders that have a "T" shape in section where the top of the girder helps form the road surface. Concrete girders are horizontal members situated beneath a bridge's deck, supported on either end and/or in the middle. They carry stresses and loads in much the same way that steel girders do. One major variation of the concrete girder is the concrete box girder, where horizontal supports are enclosed at the bottom and top to form a hollow space in the middle as viewed in section. Most reinforced concrete was built using the cast-in-place method, where liquid concrete was poured into wooden forms built at the bridge's location. Pre-cast methods were developed during the mid-20th century, where reinforced concrete could be poured elsewhere and moved into place after it was set. As explained below, the pre-cast method was particularly used after the development of prestressed concrete.

Between the 1930s and 1950s, two important design developments emerged in concrete construction that led the Division of Highways to eventually build over 90 percent of the state's bridges in concrete. The first of these innovations came in 1938, when the Division of Highways introduced reinforced concrete box girders in California.[94] Their use steadily increased through

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[94] Division of Highways and general bridge literature lists 1938 as when concrete box girders were introduced in California, a year after the first concrete box girder was built in the United States in Washington state. Research during this project indicates that the Division of Highways built at least one box girder bridge prior to 1938. The Pescadero Creek or Anderson Bridge in San Mateo County (35C0053) was built in 1937. It is a rigid-frame

the 1950s and 1960s. The second innovation was the introduction of prestressed concrete, which was first used in California in 1951. During the 1950s, non-prestressed reinforced concrete continued to be used on a majority of concrete bridges. At times, this type accounted for 75 percent of all bridges constructed in a single year. However, by the end of the decade, prestressed concrete bridges had grown to 15 percent of the new bridge construction annually in the state, and its popularity continued to increase relative to other bridge types. During the 1960s and through the height of bridge construction in California during the early 1970s, prestressed concrete accounted for roughly half of all concrete roadway bridges and 40 percent of total roadway bridges constructed in the state. The design innovation of prestressed concrete is fully discussed below.[95]

Existing examples of the various types of concrete bridges from the 1930s, 1940s, and 1950s provide key evidence about the rise and decline of certain types of concrete bridges in California. Extant concrete bridges in California constructed during this time represent early examples of concrete box girder bridges and prestressed concrete bridges, later examples of concrete arches, and ample supplies of concrete slabs, tee beams, and girders. During this period, reinforced concrete, and later prestressed concrete, was built in a variety of forms using both simple and continuous spans.[96] As the demand for wider spans grew, continuous concrete was built with greater frequency. Continuous concrete had first been used in bridges during the early 20th century, but the first major use of continuous concrete girders reinforced with steel rods in the United States was in 1932, when the Western Hill Viaduct was completed in Cincinnati, Ohio. The early examples of continuous concrete spans were essentially steel girders encased in concrete. Following the successful completion of the viaduct, contractors increasingly used this new method of construction. Continuous concrete was advantageous because it could be used in long-span forms, a fact that became increasingly important following World War II when California's highway and freeway system expanded, necessitating many new bridges with wide spans.[97]

Few concrete box girders were constructed in the state until after World War II, when their numbers increased quickly. Following the introduction of prestressed concrete in California, only a handful of bridges were built as box girders during the 1950s. Instead, most prestressed concrete bridges built before 1960 were slabs and girders. Prestressed concrete slab and tee beam bridges came to their zenith during the late 1950s, but decreased during the 1960s and 1970s when the use of prestressed concrete for box girders came into wide use. Prestressed concrete girder bridges continued to be steadily built from the 1950s into the 1970s. The largest

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reinforced concrete bridge with two hollow box girders with a central opened area between them. Thus this bridge appears to be an early variation of this bridge type and does not constitute the full expression of the concrete box girder. This may explain why it has been overlooked as among the first concrete box girder bridges in the state.

[95] Division of Highways, *Tenth Biennial Report*, 1936; Division of Highways, *Eleventh Biennial Report*, 1938; Division of Highways, *Twelfth Biennial Report*, 1940; Division of Highways, *Thirteenth Biennial Report*, 1942; Division of Highways, *Fourteenth Biennial Report*, 1944; and Division of Highways, *Fifteenth Biennial Report*, 1946.

[96] As with steel, simple concrete spans are supported on either end. Continuous concrete spans are generally longer than simple spans and are supported in more than two locations. Continuous concrete, like its counterpart in steel, provides more rigidity in bridge designs and thus could be used in wider spans.

[97] Carl W. Condit, *American Building: Materials and Techniques*, 258; Carl W. Condit, *American Building Art: The 20th Century*, 99-100, 208.

decline in concrete bridge design was the use of concrete arches. Several hundred concrete arches had been built in California during the late 1920s and early 1930s, but construction of new concrete arches quickly fell off during the late 1930s, dwindling to only a few newly built arches in the late 1950s. There are also five types of concrete bridges that were built less frequently in California: frame concrete bridges, concrete bridges constructed with a girder / floorbeam system, concrete through arches, single chamber box girders, and prestressed continuous concrete tee beams.

3.3.2.1. Concrete Box Girders

The use of reinforced concrete developed in the United States and Europe during the late 19th century and was commonly used in California bridges by the 1910s. Many early reinforced concrete bridges in the state imitated designs of masonry bridges, with wide piers and abutments supporting closed spandrels and arched barrels. Compressive loads and stresses of such bridges were carried in a way similar to their stone antecedents, with little need to address tensile loads. Open spandrel arch bridges continued to carry loads similarly, but were designed to allow for a lightness in appearance not feasible with stone. In some cases open and closed spandrel arches emphasized Classically-inspired design. Reinforced concrete was also used for bridge girders during the early 20th century, carrying loads in much the same way that steel girders do on steel girder bridges, as well as for rigid and monolithic slabs. Unlike arches, girders and slabs were limited in size by their inherent tensile weakness, despite their steel reinforcement. During the 1920s and 1930s, design and construction costs of concrete bridges rose, because steel supply was limited on the West Coast. At the same time, there was growing demand for longer and wider bridges, skewed bridges permitting straighter, more efficient, and safer roadways, and aesthetically pleasing structures that more clearly illustrated harmonious proportion and transportation efficiency. Concrete box girders were among the designs developed to address those issues.

Initially developed by French engineer Eugene Freyssinet during the 1920s, the earliest examples of the concrete box girder were constructed in Europe. The hollow box design of concrete box girders was devised to provide greater torsional strength (to resist twisting) than concrete girders of similar or even larger proportions while continuing to improve resistance to bending.[98] The benefits of employing such a structure included use of shallower girder depth and the requirement for less material to construct girders. Box girders also reduced the volume of expensive, labor-intensive frameworks, and provided an efficient and cost-effective design for spans up to 100 feet. Longer spans usually employed prestressed concrete. Box girders also provided engineers greater flexibility in designing skewed bridges. The hollow box also provided engineers space in which to conceal necessary utilities in grade separation structures.[99] The slim, curving characteristics of the box girder contributed to the minimalist, sometimes graceful, architectural quality of bridges constructed during the Modernist era of the mid-20th century, such as the Alameda Creek Bridge in Niles Canyon built in 1948 shown in Figure 12.

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[98] Carl W. Condit, *American Building: Materials and Techniques*, 258-259; Oris H. Degenkolb, *Concrete Box Girder Bridges*, American Concrete Institute Monograph No. 10, (Ames, Iowa: Iowa State University Press and American Concrete Institute, Detroit, 1977), 1.
[99] L.C. Hollister, "Careful Design Cuts: Construction Costs on Los Angeles Freeway Structures," *Civil Engineering*, May 1950, 43.

Instead of being formed into arch shapes imitative of masonry, reinforced concrete box girders (as well as other types of concrete girders) were used to convey the nature of the material, emphasizing its strength and monolithic character.[100]

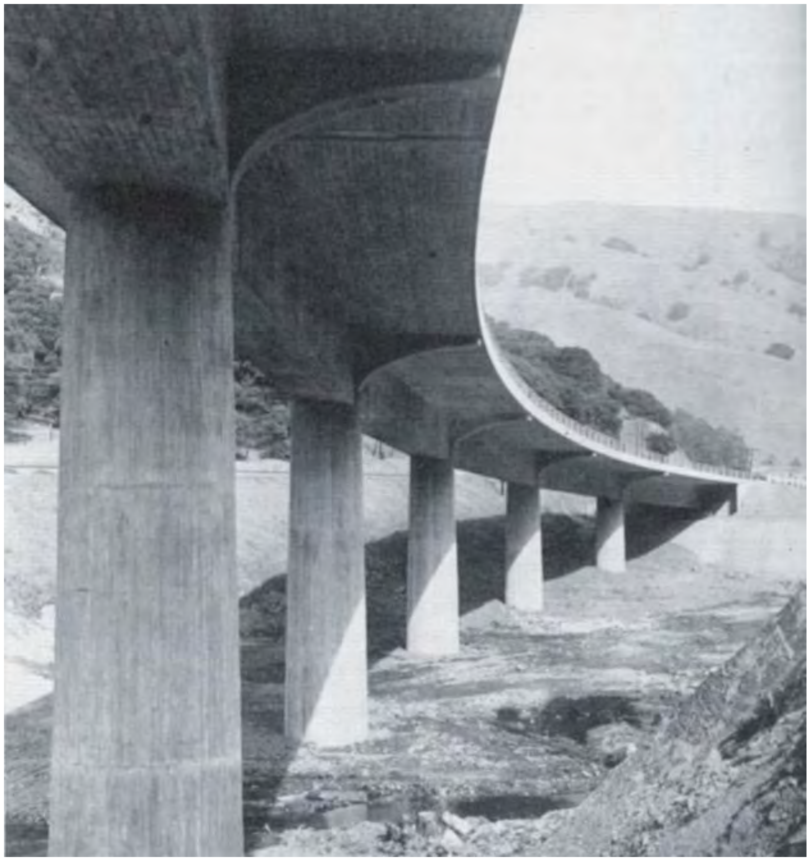

Figure 12: Alameda Creek Bridge (33-0039), Niles Canyon, Alameda County, 1948.

Contractors, with cooperation from the Bridge Department, found ways to construct box girders economically by limiting the high-quality finished form work to the soffit and sides using old lumber and scraps (described as "anything mortar-tight") for the remaining 80 percent of form work. Many times the interior forms were never removed. Box girders became the least expensive bridge type for spans over fifty feet. Designers modified the basic box girder to decrease the visual impact of the bridge superstructure and provide slender crossings that would give the appearance that roadways soared across the intervening spaces, a view that was particularly effective with tapered piers. Designers sloped the girder sides to de-emphasize the structure's depth, and rounded the corners to make the box form less defined. Overhangs cantilevered from the bridge deck were extended to provide more shadow and definition to this bridge type. Designers later formed box girders into continuous curves to form what was called a "bathtub" section, which was also achieved more economically by employing a large rounded fillets at the bottom of girders.[101]

[100] David B. Steinman and Sara Ruth Watson, *Bridges and their Builders*, (New York: Dover Publications Inc., 1957), 279.
[101] Arthur L. Elliot, "Fifty Years of Freeway Structures," 1988.

The greatest number of existing box girder bridges in California constructed prior to 1960 are located in Southern California, largely in Los Angeles County. As is the case across the state, most of these structures are freeway bridges taking roadways over surface streets and waterways, or used for overcrossings. One of the most well-known examples of reinforced concrete box girder bridges is the Four Level Interchange in Los Angeles, constructed in 1949 (53 0622). Elsewhere reinforced box girders were used for some long bridges, though with many spans, like Ten Mile Bridge (10 0161) on State Route 1 in Mendocino County north of Fort Bragg. This 1,351 foot long structure was completed in 1954 replacing a 1915 timber deck truss. Running along the Mendocino Coast, the Division of Highways touted the structure as "pleasing and harmonious" with its surroundings when completed.[102]

3.3.2.2. Prestressed Concrete Bridges

As stated, concrete is naturally strong in compression but weak in tension. Even concrete reinforced with steel rods has limited tensile strength. This low tensile strength makes concrete susceptible to cracking. With greater demands for concrete bridges and longer concrete spans, and the increasing costs associated with massive form work required for concrete arches, engineers in the 1920s and 1930s began experimenting with methods to place longitudinal force on structural concrete to raise its capacity to withstand bending, shear, and torsion (twisting). This type of linear compressive force is referred to as "prestress," and it is applied to structural elements prior to their installation and exposure to dead loads (the weight of a bridge structure itself) or live loads (traffic, wind, water). Typically, the reinforcing bars are stretched (placed in tension) prior to pouring the concrete. After the concrete is poured and sufficiently hardened, the tension is released from the steel. The resulting contraction of the steel induces a compression force in the concrete to which the steel has bonded. The advent of this concept allowed engineers to produce longer concrete spans and provided them with greater control over the amount of load bridges could withstand. Prestressing allowed engineers to make structural members as flexible or rigid as needed without influencing the strength of the concrete, a flexibility more difficult to achieve with reinforced concrete. Ultimately, this technology led to construction of segmental and cable-stayed concrete bridges of a size that could only be achieved with the ability to construct very large spans. There were many economical advantages of prestressing, and as discussed in Section 3.1, the process also permitted the implementation of stylistic tenets of Modernism as the strength achieved allowed structures to be about 25 percent shallower than those constructed in conventional reinforced concrete. Shallower structures also provided cost savings, requiring less concrete and less steel reinforcement in both girders and beam as well as in abutments and piers. Cost savings also came from the ability to pre-cast units and reuse formwork for large quantities of girders and beams. Additional benefits derived from decreased maintenance costs over time and the longer working life of such structures. Conversely, the quality of those materials needed to be of higher quality and the prestressing was also more expensive to construct than simple reinforcement.[103]

[102] "New Span: Dedication of Ten Mile River Bridge and Approaches Held," *California Highway and Public Works*, November-December 1954, 22-23.
[103] Edward G. Nawy, P.E., *Prestressed Concrete: A Fundamental Approach*, (Upper Saddle River, NJ: Prentice Hall, 2000), 1-5; and Arthur L. Elliot, "Fifty Years of Freeway Structures," 1988, 5.

The concept of prestressing dates to the 19th century, but was not perfected for large scale construction until around 1940. Early prestressing systems suffered from loss of the prestress over time. One such concept was developed by California engineer P.H. Jackson, who patented a system in 1872 that used a tie rod to construct concrete beams or arches by placing individual blocks under compression from either end. Engineers in the United States and Europe worked on the problem of prestress loss during the early 20th century, developing systems for post-tensioning rods. It was French engineer Eugene Freyssinet who proposed and built a system using high-strength and high-ductility steels as a way to overcome prestress loss. Starting in the late 1920s, Freyssinet conceived of a prestressing system using a conical wedge anchor and twelve-wire tendons that became the most well-known and well-accepted system for prestressing. The destruction caused by World War II in Europe necessitated prompt reconstruction of bridges. The result was a growing demand for prestressed concrete during the postwar period, as both steel and concrete were in short supply. Variations on Freyssinest's system evolved during the postwar period. One designed by Belgian engineer G. Magnel used flat wedges that accommodated the prestressing of two wires simultaneously. University of California Berkeley civil engineer professor Tung Yen Lin later devised a method of load-balancing that was particularly useful in continuous concrete structures. The development of prestressed concrete was greatly influenced by the enormous demands accompanying postwar freeway construction and the Interstate Highway System. The wave of construction spawned a competitive industry that strove to solve the fabrication and construction problems, and created a dynamic climate where innovative engineering techniques were tested and applied. Unlike early concrete bridges types, this technology led to the formation of specialized companies for its construction. These companies would be hired by the general contractors to conduct the prestressing for concrete components of bridges.[104]

The first prestressed concrete bridge constructed in the United States was erected at Walnut Lane in Fairmont Park, Philadelphia, Pennsylvania in 1949.[105] The Division of Highways built the first prestressed concrete bridge in California (and in the West) in 1951. The new bridge was a single span pedestrian bridge over the Arroyo Seco Channel, which ran roughly parallel to the Arroyo Seco Parkway. Professor T.Y. Lin helped calculate the stress for the structure that Bridge Department Associate Bridge Engineer W.J. Jurkovich designed. Although the shortage of steel in the United States after World War II was less of a problem as compared with the situation in Europe, American engineers valued prestressed concrete for its potential of precasting and economy. Although California's first experiment with constructing a prestressed concrete bridge was more expensive and complex than construction of a comparable cast-in-place reinforced concrete structure would have been, during the 1950s the Division of Highways escalated its prestressed concrete bridge program as the design's promised economy was realized. Between 1950 and 1960, bridge engineers embraced the new technology and clearly shifted their preference from structural steel to reinforced concrete and prestressed concrete. For example, 34 percent of bridges built in 1950 were structural steel, while 66 percent were built in reinforced concrete. By 1955, steel made up only 23 percent of new bridges, while 74 percent

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[104] Edward G. Nawy, *Prestressed Concrete*, 5-6; University of California Berkeley Civil and Environmental Engineering website faculty list, no date, online at http://www.ce.berkeley.edu/faculty/ (accessed November 2002); and John J. Kozak and Thomas J. Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," *Prestressed Concrete Institute Journal*, September 1976, 90-92 and 111.

[105] The Walnut Lane Bridge in Philadelphia was listed in the National Register in 1988.

were reinforced concrete and three percent were prestressed concrete. Five years later, the shift was largely complete with only 9 percent of new bridges constructed in structural steel, 72 percent in reinforced concrete and 19 percent in prestressed concrete.[106]

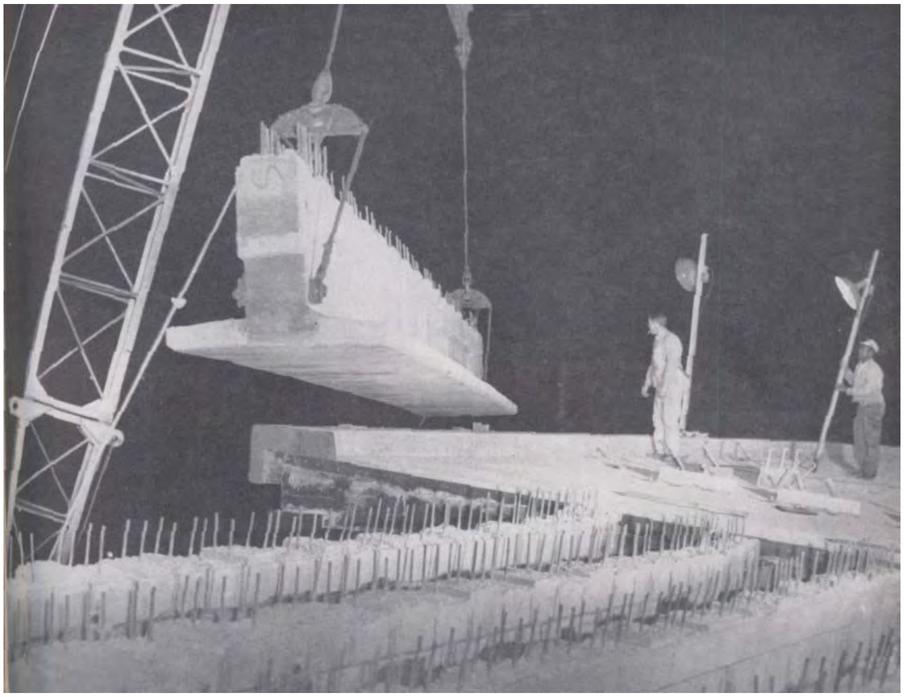

Figure 13: Placing inverted tee beam prestressed girder, San Bernardino-Santa Ana Freeway Interchange, 1955.

In the formative years of prestressed concrete bridge building in California, Bridge Department engineers were uncertain as to what type of design would be most economical. Often they would compare various prestressed concrete designs to structural steel and reinforced concrete alternative before selecting an appropriate design for a specific project. Over time, bridge construction contractors increasingly selected prestressed designs when given a choice. Most of the early prestressed concrete bridges in California were constructed with girders, tee beam girders, or slabs used as precast concrete replacements for rolled or welded steel girders, such as the inverted tee beam design shown in Figure 13. The Division of Highways used only limited prestressed concrete box girders during the 1950s. At the time, there were few, if any, formal specifications for prestressed concrete bridges. Individual engineers in the Bridge Department constantly improved the design of I and T shaped girders, leading to different girder shapes, dimensions, and capabilities that were often unusable in subsequent projects. The federal Bureau of Public Roads did not publish its first engineering specifications manual for prestressed concrete bridges until 1954, and Professor T.Y. Lin's seminal work on the topic, *Prestressed Concrete Structures*, was not published until 1955.[107]

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[106] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 92; "California Builds a Prestressed Bridge," *California Highways and Public Works*, January-February 1951, 58; Robert M. Barton, "Prestressed Bridge: First of Its Kin in State is Built in Los Angeles," *California Highways and Public Works*, March-April, 1951, 2-5 and 28.

[107] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 92-97 and 104.

During its first decade of use in California, prestressed concrete, mostly pre-cast, was successfully used for the myriad of new short span overcrossings and undercrossings required by the growing freeway system, in places where minimal structure depth was required, and where falsework had to be limited or not be used, such as over railroad tracks. The Division of Highways also used prestressed concrete in piles and for decks, making them lighter, easier to install, and more durable than had previously been achieved with conventional reinforced concrete. Slender piers with greater taper could also be constructed. The Division of Highways built the state's first prestressed concrete vehicular bridge in 1953 in Fresno for the Weber Avenue Overcrossing (42C0071) at Belmont Avenue. Prestressed concrete was chosen in part to reduce costs while permitting flat approaches with maximum roadway clearance. There were other advantages. The new structure would not disrupt traffic during construction because no falsework was required; furthermore, existing concrete walls associated with an adjacent railroad underpass could serve as abutments. The Freyssinet Company provided the prestressing for the bridge. With the Arroyo Seco bridge experience and accumulated information collected from other states, the Division of Highways concluded that test girders were not required for this structure. The following year a further advance in prestressed concrete in California was built on Route 2 / US101 in Salinas in Monterey County. The Division of Highways built the John Street Overcrossing (44 0121) with a continuous cast-in-place prestressed concrete box girder and appears to be the first of its kind built in the state. The structure was two spans, 100 feet and 93 feet, and had only a four foot depth, making it roughly one and a half feet shallower than a traditional reinforced concrete bridge. The span lengths would have been impractical in standard reinforced concrete. The low depth to span ratio was attractive because it required less concrete, which, in turn, was beneficial to offset poor soil conditions at this location. Finally, the roadway did not need to be built as high as it would have otherwise needed to be. The cast-in-place technique used here foreshadowed practice that came into wide use a decade later. While relatively fewer box girders were constructed in prestressed concrete during the 1950s, it became by far the most abundant type of prestressed bridge in the state during the post-1960 period.[108]

With the great variety of prestressed structures designed at the time, there are various examples where the Division of Highways constructed bridges that tested the limitations of the new material. In 1954, the Division of Highways installed a 62 foot prestressed concrete slab for the Bacon Street undercrossing at Bacon Street on US101 in San Francisco. This slender slab bridge (340057L) was prestressed both transversely as well as longitudally by the Freyssinet Company and as a result was only two feet, two inches deep. One of the longest prestressed concrete bridges of this early period crosses the Santa Maria River between San Luis Obispo County and Santa Barbara County on Route 1. The Division of Highways constructed the 24 span, 1,200 foot structure (49 0042) in 1955 with 120 fifty foot tee beam girders. The bridge prestressing was done by Prescon Company for the general contractor Granite Construction Company. In 1957, District 7 employed prestressed concrete girders for some bridges on the San Bernardino Freeway (I-10) such as the Bess-Frazier Avenue overcrossing (53 1295), a four span girder

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[108] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 92-97 and 104; Thomas J. Bezouska, "Precedent: First Pre-stressed Highway Bridge Planned for Fresno," *California Highways and Public Works*, September-October 1952, 40-42; E.J.L. Peterson, "Salinas Freeway: First Unit, Market Street to North Main Street, Opened," *California Highways and Public Works*, March-April 1954, 38; and Arthur L. Elliot, "Fifty Years of Freeway Structures," 1988, 5-6. Box girders are also the most dominate type of prestressed concrete bridges in California for all years combined.

bridge that had five foot deep cast-in-place I-girders and pre-cast diaphragms. Notably, the slow implementation of this technology for vehicular traffic is reflected in that nearly a quarter of Los Angeles' prestressed concrete bridges from the 1950s are pedestrian overcrossings. One such example is the bridge over US101 at DeValle Street (53 1162), which is a more than 200 foot long, four span continuous slab built only one foot six inches deep.

Unlike older bridge types in California, it is likely that few prestressed concrete bridges have been replaced, though many have been widened, lengthened, or otherwise modified. The greatest concentration of prestressed concrete bridges in the state from the 1950s is in Southern California, with most in Los Angeles and Orange counties, followed by San Bernadino and Riverside counties. In Northern California the greatest volume of prestressed concrete bridges is found in the San Francisco Bay Area, with the greatest concentration of this bridge type from this period in Santa Clara County. Second tier cities such as Fresno, Sacramento, and San Diego saw construction of a high proportion of the prestressed concrete bridges during this period. Elsewhere across the state, the patterns are less discernable. In northern coastal counties, for example, more were built in Mendocino County during the 1950s, than in neighboring Sonoma and Humboldt counties.

During the 1950s, Bridge Department engineers and contractors encountered various challenges while designing and constructing various types of bridges using prestressed concrete. There were problems encountered with the materials (steel and concrete), the installation of bridge components, and many unconventional designs being tested during this period. Rusting steel, a condition that weakened prestressed concrete structures, was an early problem for contractors and state inspectors. Corrosion inhibitors and new packing forms were developed to largely eliminate rust from the steel that was used for prestressed concrete. Mixing and pumping grout, a malleable filler, around the steel tendons, i.e. rods, wires, strands, after they were prestressed also posed challenges for bridge engineers and contractors. Grouting was done to increase the bridge's load capacity and to protect the steel from rust. Improved equipment and methods solved most of the grouting problems by the late 1950s. Prestressed structures required concrete of a higher quality than had been previously used, and contractors had to conform to higher quality standards using less water, more cement, and finer aggregate. Other problems stemmed from balancing the expense of high quality materials and requirements for shallow structures. To address this engineers modified designs such as using thicker bottom slabs near interior supports on concrete box girders to provide the necessary strength requirements without having to use cost-prohibitive high strength concrete. During this period, general contractors often had little experience in prestress methods. They would purchase the fabricated prestressed tendons and installed them incorrectly. This led to poor workmanship on some bridges. Faced with an increasing variety of girder forms, the Bridge Department began to standardize girders in 1958 so as to better achieve the promised economy of prestressed concrete. The I girders continued to be used, while the use of T girders declined steadily during the 1960s because of the T's tendency to creep upwards, creating bumpy road surfaces.[109]

Following acceptance of the Freyssinet prestressing method, assembled world-wide by the Freyssinet Company, several other prestressing systems emerged during the post-World War II period. The steel in California's first prestressed concrete bridge over the Arroyo Seco parkway

[109] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 92-98.

was prestressed by the Prestressed Concrete Corporation or Prescon which used a button head wire system. Other systems of the period included stress steel rods, various wire systems, and multi-wire strand systems. "Harping" or "deflection" techniques were improved for steel tendons during the 1950s, and Freyssinet also improved on his original strand and steel cone system during the late 1950s. Before the 1960s, rods were predominately used in short span prestressed concrete bridges while the wire systems of such companies as Prescon, Ryerson, and Western Concrete Structures were use on longer continuous structures.[110]

By 1960, the Division of Highways had successfully integrated prestressed concrete into its bridge design and construction practice, yet many innovations were still to come. Precast I beam and tee beam girders were only effective, for instance, in lengths less than 100 feet. FHWA freeway guidelines from the 1960s encouraged increased vertical and horizontal clearances and the elimination of columns and bents from the roadway to improve driver safety. This required longer spans over four, six, and eight lane roadways. For instance during the 1950s, the Division of Highways constructed overcrossings with two main spans up to 90 feet long and two 50 foot side spans using a central bent and two side bents between abutments. In response to FHWA guidelines, the Division of Highways was able to remove the side bents by using box girders and cast-in-place designs whose lengths could span well above 100 feet. This resulted in long two span structures that had not only safety benefits, but also presented a new aesthetic result and managed cost savings over the four span I or tee beam bridge. Cast-in-place and box girder designs also provided design flexibility for the skews and curves necessary for the complex requirements of interchanges and grade separations. Cast-in-place designs often required post-tensioning of the steel tendons, i.e. prestressing the concrete after it was set. Where falsework was too expensive or complicated, pre-cast components continued to be more economical. Later innovations in prestressed concrete, that are beyond the scope of this context, included the development of rigid tendon conduits, new prestressing techniques, construction of prestressed railroad bridges, and the specialization of prestressed tendon installation.[111]

3.3.2.3. Concrete Arch Bridges

The increased cost of labor and materials associated with the construction of concrete arch bridges, including the construction of extensive falsework and manual pouring of concrete, led to the declining use of this type of bridge starting in the late 1930s. Concrete arches were largely replaced when the Division of Highways fully implemented other more modern concrete types such as the reinforced concrete box girder and prestressed concrete girders. The falsework required became more expensive following World War II when there was a lumber shortage spurred by the vast housing construction programs in the state. The labor required grew increasingly more expensive as postwar unemployment dissipated. Even so the Division of Highways continued to consider construction of concrete arches during the immediate postwar period where, for example, there was steep terrain and a wide span. Few were built.

All of the 44 extant concrete arch bridges in California built between 1936 and 1959 are deck structures. The greatest concentration of concrete arch bridges from this period in the state are in Los Angeles County, and most of concrete arch bridges from this period were built prior to the

[110] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 101-103.
[111] Kozak and Bezouska, "Twenty Five Years of Progress in Prestressed Concrete Bridges," 98-104.

end of World War II. Two of the most well-known concrete arch bridges in Northern California from this period are located along State Route 1 in Mendocino County Jug Handle Creek (1938) (10 0145) and Russian Gulch (1940) (01 0051). There are also three concrete arch bridges, for example, built in 1939 in Yosemite National Park along Big Oak Flat Road.

3.3.2.4. Concrete Slab, Girder, and Tee Beam Bridges

Concrete and continuous concrete slab bridges are the most abundant type of existing bridge constructed in California between 1936 and 1959. They account for over a quarter of all bridges from that period. Next to steel and continuous steel girder bridge, concrete and continuous concrete tee beam are also among the most common type in the state built during this period. Concrete slabs, including continuous concrete, were the cheapest bridge type to construct and among the simplest to erect. These bridges, used for the short spans usually not longer than thirty feet, needed simple form work, were quickly constructed, and require relatively little maintenance. Similarly, tee beams were cheap to build and had low maintenance costs. Used for spans shorter than 80 feet, generally, tee beams required form work that was a little more complex than that for slabs. Other than in tee beam and box girder form, very few other reinforced concrete girder (non-prestressed) bridges were constructed during this period.[112]

The greatest concentrations of concrete slab and tee beam bridges built between 1936 and 1959 are in the southern Central Valley and in the Los Angeles area, particularly in Los Angeles, Tulare, and Fresno counties. This is followed by the San Francisco Bay area and the northern Central Valley, particularly in Santa Clara, Sonoma, Sacramento, and Butte counties. There are also many such structures in San Diego and Riverside counties. This pattern follows not only the population centers of the state, but also where most of the state's freeways were constructed during this period. The fewest concrete slab and tee beam bridges from this period are found in the eastern part of the state in Mono, Inyo, Sierra, Lassen, and Alpine counties. A majority of the small number of concrete girder bridges which are not tee beams or box girders, are located in Northern California, with the most found in Plumas and Sutter counties. It is unclear why these counties chose to use this bridge type more often than other counties during this period. Seventeen counties have only one bridge from this period that falls into this category.

3.3.3. Timber

California's earliest bridge builders constructed bridges in timber as it was typically the only available material. By the late nineteenth and early twentieth century, engineers increasingly opted for steel and concrete bridges rather than timber as a result of the growing demands of automobile use and advances in bridge designs.[113] Although engineers preferred steel and concrete for roadway bridges, they continued to construct timber bridges, mostly on secondary roads, in the 1930s, 1940s, and 1950s. During the early 1930s, the Division of Highways built several timber arch and truss spans, including a bridge over Dolan Creek on Highway 1 in Monterey County completed in 1934. Featuring a 180 foot arch span with two 38 timber stringer

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112 Department of Public Works, Division of Highways Bridge Department, *Bridge Planning and Design Manual*, Vol. 2, 1955-1966, (revised January 1961).

113 Duwadi, Sheila Rimal and Michael A. Ritter, "Timber Bridges in the United States," *Public Roads On-Line*, Winter 1997, online at: http://www.tfhrc.gov/pubrds/winter97/p97wi32.htm, (accessed December 3, 2002).

spans and thirteen 19 foot trestle spans, the Dolan Creek Bridge was pre-fabricated near Monterey and constructed in sections at the site. The Dolan Creek Bridge was among the first bridges built by the Division of Highways to use new European timber connectors. These connectors, or interconnected metal rings which transfer the weight from one piece of wood to another, improved the strength of the timber joint, the weakest section of any timber structure.[114] The redwood Dolan Creek Bridge was a victim of the moist sea air, however, and was replaced in 1961.[115] Although no timber arch bridges were built in California between 1936 and 1959, the Division continued to use the connectors in other timber bridges built during that period.

Three types of timber bridges were built in California between 1936 and 1959: slab, stringer, and truss. Douglas fir, grown in California as well as Oregon and Washington, as well as California redwood were used most commonly for timber bridges in the state, although some counties used California red fir and ponderosa pine. The California Division of Highways typically did not use California red fir or ponderosa pine except when constructing temporary bridges. During this period, the Division of Highways commonly used creosote pressure-treated wood, but also used untreated Douglas fir.[116] Most of California's timber bridges built during this period are timber stringer or girder bridges. Only small number of timber slab and timber truss structures were built during this period. The greatest concentrations of timber stringer bridges are in the central part of the state in San Luis Obispo, Fresno, and Merced counties. The greatest concentration of timber slab structures are located in remote or once rural areas of Los Angeles County, all of which date to between 1945 and 1956. Like other timber bridges, timber trusses were largely built by counties in rural areas such as those found in Los Angeles or Humboldt counties.

No covered bridges were constructed in California between 1936 and 1959. Indeed, the last two covered bridges that had been built on state highways were replaced in 1950. The US Bureau of Public Roads built these structures in the early 1920s on what is now State Route 96, which follows the Klamath River from Weitchpec to Interstate 5 near Hornbrook. Built originally as part of the first through road in western Siskiyou County, the timber truss bridges were covered with sheet metal sides and roofs. By 1950, both were considered narrow and in need of repair. They were replaced with concrete and steel deck girder bridges that provided two lanes of traffic and no vertical clearance issues. Central to their replacement was the need for improved roads for logging trucks and transportation of heavy mining equipment.[117]

3.3.4. Grade Separations / Interchanges

Historically, bridges were constructed to span natural barriers such as waterways or canyons. As modern transportation systems developed in the early 20th century, it became increasingly important to separate various forms of transportation. Initially, this meant separating the dominant form of transportation, railroads, from the growing number of motor vehicles. Over

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[114] Stewart Mitchell, "New Type Timber Arch Bridge Spans Dolan Creek Gorge on Coast Highway," *California Highways and Public Works*, February 1935, 26.
[115] California Department of Transportation, *Historic Highway Bridges of California*, 146.
[116] Stewart Mitchell, "The Engineering of Timber Highway Structures." Paper presented at the 30th Annual Road School Purdue University, January 26, 1944, 3.
[117] "Covered Bridges: Last Two of Such Structures Removed from State Highways," *California Highways and Public Works*, November-December 1950, 12-13.

time, automobiles and trucks began supplanting railroads, and larger and newer highways and freeways were developed, necessitating the separation of motor vehicle traffic. From the 1930s through the 1950s, grade separations in general became an increasingly larger portion of the state's bridges. Table 1 shows the growing percentage of grade separations in the total bridge population in California between 1936 and 1958. Just as had been the case with railroads, roadway grade separations were needed to improve safety and reduce delays caused by intersections. While between 1936 and 1959 there was modest growth of railroad separations throughout the state, there was a vast escalation of roadway grade separation construction, as illustrated in Table 2. In the mid-1930s, well over 90 percent of all grade separations in California were located at railroad tracks; very few roadway grade separation structures had been built. By the late 1940s only two thirds of grade separations were at railroads, and by the end of the 1950s, railroad grade separations accounted for approximately a quarter of grade separations in the state. The remainder divided roads and highways from one another. In 1958, there were less than 400 railroad grade separations and 1,150 roadway grade separations, accounting for nearly three quarters of the state's grade separations.[118]

The county with the greatest number of existing grade separations built between 1936 and 1959 is Los Angeles. The next greatest concentrations of grade separations, albeit far fewer than in Los Angeles, are San Diego, San Bernardino, Alameda, Sacramento, Contra Costa, and San Francisco counties; a trend that mirrors the development of freeways in metropolitan areas. The counties with the fewest grade separations in the state built during this period are rural Amador and Tehama, followed by Siskiyou, Lassen, Plumas, Butte, Colusa, Napa, and Stanislaus. Over fifty percent of all grade separations built between 1936 and 1959 were constructed between 1956 and 1959, with only a third built in the decade following World War II. Approximately one third of all extant grade separations built between 1936 and 1959 are reinforced concrete or prestressed concrete box girders. Another quarter from this period are steel girders, and concrete and continuous concrete slab and tee beam bridges each account for less than twenty percent of existing grade separations from this period.

The following discussion describes the historical events and trends associated with the development of grade separations in California, first with railroads and then with highways, including freeways. Throughout this period, the Division of Highways used specific terms for various grade separation structures. Railroad grade separations are overheads and underpasses, where a roadway passes over and under railroad tracks respectively. Roadway grade separations are overcrossings, where a county road or city street passes over a state highway, and undercrossings, where a county road or city street passes under a state highway or where one state highway passes under another state highway. Grade separation bridges, by type and material, are discussed in Chapter 3 along with all bridges.

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[118] Unlike other statistical analysis provided in this report, numbers provided for grade separations come from two sources. The first is from tabulations from the Division of Highways Biennial and Annual reports from the period. The second source is filtering the data in the Caltrans database to discern between bridges that pass over natural barriers, such as waterways or canyons, versus passing over other roads. The statistical analysis of existing grade separations is based on a sample of 1274 overheads, underpasses, overcrossings, and undercrossings, and is thus not exact. The database does not readily indicate which bridges are grade separations. Thus the analysis of grade separations has a wider margin of error than analysis on other bridge types found in this report.

Table 1: Growing percentage of grade separations to total existing bridge population – 1936 to 1958

Year	Bridge total	Grade Separation total	Grade Separation Percentage of total
1936	3458	255	7%
1938	3968	285	7%
1940	4208	365	9%
1942	4283	401	9%
1944	4374	380	9%
1946	4443	382	9%
1948	4388	392	9%
1949	4483	590	13%
1950	4504	516	11%
1951	4488	546	12%
1952	4507	574	13%
1953	4499	613	14%
1954	4600	771	17%
1956	4760	1110	23%
1957	5086	1327	26%
1958	5296	1548	29%

Table 2: Changing Percentage of Railroad and Roadway Grade Separations to Total Grade Separation Population – 1936 to 1958

Year	Grade Separation total	Railroad total	% of total	Roadway total	% of total
1936	255	239	94%	16	6%
1938	285	253	89%	32	11%
1940	365	257	70%	108	30%
1942	401	266	66%	135	34%
1944	380	254	67%	126	33%
1946	382	258	68%	124	32%
1948	392	261	67%	131	33%
1950	516	293	57%	223	43%
1952	574	303	53%	271	47%
1954	771	313	41%	458	59%
1956	1110	345	31%	765	69%
1958	1548	398	26%	1150	74%

3.3.4.1. Railroad Grade Separations

Motor vehicle traffic grew exponentially on California's roads and highways during the 1910s and 1920s. In 1907, there were only 14,000 motor vehicles registered in California. By 1914 that number had risen to over 123,000 and by the end of the 1920s there were nearly two million motor vehicles registered in the state. The Los Angeles area had the most cars and other motor vehicles in the state (some forty percent by the mid-1930s). By 1940, there were over 2.8 million vehicles registered in California. As motor vehicle traffic increased, so did accidents, particularly at railroad grade crossings.[119]

Although the hazardous conditions associated with at-grade railroad crossings were recognized early on, it took many years to address what were referred to in 1921 as "some of the worst death traps" in California when the grade separation program began in California. From 1916 onward the California Railroad Commission, and later, the Public Utilities Commission, studied and rated grade crossings.[120] In 1924, there were 102 fatal motor vehicle accidents at grade crossings state-wide. By 1927, that number had risen to nearly 200, with Los Angeles County, Alameda County and Santa Clara County with the largest rates of accidents, fatalities, and injuries at railroad grade crossings in the state. These statistics were alarming to many at the time, including automobile supporters, railroad representatives, and government officials. The figures are even more striking when compared with more recent figures. In 1928, there over 1.8 million vehicles registered in California, and there were 165 persons killed and 732 injured at railroad grade crossings that year. In 2001 over 29.6 million vehicles were registered in California and only 54 fatalities and 49 injuries occurred at railroad crossings statewide. While improved safety devices at crossings, increased education, grade crossing closures, and abandonment of branch lines and spurs contributed to this decrease, construction of grade separations significantly reduced death and injury where motor vehicles and trains intersect.[121]

For example, in the period between the World Wars (1918 to 1941), there were some four thousand grade crossings along the Southern Pacific Railroad rails alone in California. During the 1930s, the number of fatalities at railroad grade crossing continued to rise. In 1931, there were accidents on over 30 percent of the Southern Pacific's grade crossings with 177 of them having five or more accidents within the year. In that same year, 422 persons were killed on Southern Pacific grade crossings and 1,399 were injured, almost all in motor vehicles. Statewide, nearly half of the accidents occurred when motor vehicles (roughly 80 percent automobiles) were struck by the front of a train, over a quarter involved motor vehicles that ran into moving trains, and over twelve percent occurred when vehicles ran through lowered gates.

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[119] *California Highways and Public Works*, February 1926, 15; *California Highways and Public Works*, May-June 1928, 31; Engineering Department of the Automobile Club of Southern California, "Traffic Survey Los Angeles Metropolitan Area," 1937; *California Highways and Public Works*, May-June 1928, 31; and California Air Resources Board, "California's Air Quality History – Key Events," updated July 24, 2002, online at: http://www.arb.ca.gov/html/brochure/history.htm (accessed November 2002).

[120] Howe & Peters Consulting Engineers, "Engineer's Report to California State Automobile Association Covering the Work of the California Highway Commission for the Period 1911-1920," July 1920-January 1921, 106.

[121] California Department of Finance, "California Statistical Abstract, Transportation and Public Utilities, Section J," October 2002, online at: http://www.dof.ca.gov/html/fs_data/stat-abs/sec_J.htm (accessed November 2002); and Federal Railway Administration, "Highway-Rail Incidents At Public And Private Crossings," online at http://safetydata.fra.dot.gov/OfficeofSafety/Query/Default.asp?page=gxrtally1.asp, (accessed November 2002).

More than half of the accidents took place in clear conditions during daylight hours with over 80 percent occurring in clear conditions regardless of the time of day. At some crossings, drivers had to contend with obstructed or obscure views of the rail line. Both the railroads and motor vehicle supporters saw grade separations as the ideal method for eliminating railroad grade crossing hazards.[122]

Grade crossings were not only hazardous but the delays caused enormous problems to the economic development of growing areas. While safety issues often garnered public attention, Division of Highways engineers often calculated the cost of retaining at-grade crossings versus construction of separations, assessing the cost for vehicles stopped at grade crossings, the cost of restricting vehicle speed on and around grade crossings, maintenance costs, and the liability expense for grade crossing accidents related death and injury. While the Southern Pacific and the other railroads in California resisted bearing the cost of grade separations, *Railway Age* reported in 1932 that eliminating train stops caused by grade crossing accidents could be appreciable for the railroads in terms of saving fuel, maintaining running times, and reduced damage to equipment.[123]

As motor vehicle traffic grew from the 1910s through the 1930s, several factors made grade crossing safety improvements and construction difficult. Not only was there much debate over which entities had control over construction of grade separations, the various parties (railroads, the state, and local municipalities) argued bitterly about how the cost of such projects should be apportioned. The Public Utilities Act of 1915 (amended in 1917 and 1927) conferred specific powers to the California Railroad Commission regarding grade separations, including the authority to choose which were to be built and the authority to apportion the funding of grade separations to the various interested parties. In theory, the commission was the controlling agency for the state's grade separations. The Public Utilities Act, however, led to considerable litigation, and the railroads continued to wrangle with the commission and local communities over placement of safety devices, construction of grade separations, and responsibility for funding. Highlighting the national scope of the grade crossing situation, the United States Supreme Court upheld the right of states to require railroads to abolish dangerous grade crossings in 1929; but litigation over the Public Utilities Act resulted in some limitations on the commission's authority. The commission's financial apportioning powers, however, were left intact. Thus, negotiating the funding of such construction proved to be one of the California Railroad Commission's more effective efforts in limiting the hazards of railroad crossings during this period.[124]

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[122] R.C. Ashworth, "Grade Crossing Report," California Railroad Commission, Engineering Department, Report #676, November 5, 1917, 1; J.G. Hunter and Steward Mitchell, "Report of the Grade Crossing Situation of Public Streets, Roads and Highways with Steam and Electric Interurban Railroads in the State of California," State of California Railroad Commission and Department of Public Works Division of Highways, Pursuant to Assembly Concurrent Resolution No. 23, Chapter 45, Laws of 1931, December 1, 1932, 56, 78-88.

[123] George T. McCoy, "39 Grade Crossings on California Highways Being Eliminated with $7,500,000 Federal Funds," *California Highway and Public Works*, October 1935, 1-6; Biennial Report of the California Highway Commission, 1936, 76; F.W. Panhorst, "Sixty-Eight Grade Separation Projects Aggregate $11,000,000," *California Highway and Public Works*, May 1939, 11-14; and California Department of Public Works, Division of Highways Bridge Department, "Bridge Construction Project Files IV-SCI-2-B (Madrone Crossing) 1930-1937," California State Archives; "Eliminating Train Stops," *Railway Age*, April 2, 1932, 92.

[124] J.G. Hunter and Steward Mitchell, "Report of the Grade Crossing Situation," 46-47; and *Sacramento Union*, February 17, 1929. The City of San Jose even took the Railroad Commission to court in 1917 over the issue of

How much the railroad paid for grade crossing upgrades was further complicated by how the Division of Highways and the counties themselves handled road and bridge funding. The state largely paid for paving roads during the 1920s and the counties were responsible for constructing bridges and other structures, including grade separations. Railroad grade separations were not only very expensive, costing up to several hundreds of thousands of dollars each, but each required enormous coordination and negotiation between the railroads, state agencies, and local property owners to obtain new right-of-way, to detour rail and road traffic during construction, and to complete the various phases of construction. This often proved to be too much for most California counties to bear. Furthermore, there were few design standards for grade separations until the state placed bridge and railroad grade separation design under the Division of Highways Bridge Department in 1924. It was at this point that the state began to set uniform standards for grade separations, as did the California Railroad Commission.[125]

Demand for grade separations was highest in California's growing urban areas. Citizen groups sprang up to address the issues. In 1929, for example, Palo Alto City Mayor, C.H. Christen, and Stanford University Engineering Professor Emeritus, W.F. Durand, organized political leaders from San Francisco, San Mateo, and Santa Clara counties to form the Peninsula Grade Crossing Conference, also referred to as the Peninsula Grade Crossing Association. Professor Durand and the association, with help from the San Francisco City Engineer, Southern Pacific Railroad, and the California Railroad Commission, studied the grade crossing situation on the San Francisco Peninsula throughout 1930 and sought ways to eliminate grade crossings. In 1931, the association's engineering subcommittee released a detailed, $9 million two-phase proposal to eliminate grade crossings on the peninsula. The "Primary Program" of the plan called for construction of grade separations at the 15 most traveled and hazardous grade crossings and closure of the 17 least important grade crossings. The "Secondary Program" would have completed the elimination of all major grade crossings in San Francisco, San Mateo, and Santa Clara counties. The conference's aim was to permit travelers to cross railroad tracks only via grade separations. At an average cost of $270,000 per grade separation, the Peninsula Grade Crossing Conference proposed legislation to fund these projects through a portion of the state's gasoline tax. While funding this sort of program was impossible, particularly during the Great Depression, the interest and detail to which this conference went indicates the seriousness of the problem at the time.[126]

In 1935, the federal government provided funding for grade separation construction with the Emergency Relief Appropriation Act (FERA). The act allotted over $7.5 million to California, where the federal government helped fund fifty new or improved grade separations. The

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apportioning the cost of constructing railroad grade separations, *San Jose* v. *Commission* (1917), 175 Cal. 284. The Commission's authority to set apportions was upheld in that decision.

[125] Biennial Report of the California Highway Commission (1926), 85-87; and F.W. Panhorst, "Sixty-Eight Grade Separation Projects Aggregate $11,000,000," 13-14; J.G. Hunter and Steward Mitchell, "Report of the Grade Crossing Situation," 47.

[126] J.G. Hunter and Steward Mitchell, "Report of the Grade Crossing Situation," 102-103. The Southern Pacific also had nearly 38 percent of California's grade separations built to date on its lines including 67 overpasses and 156 underpasses. As of January 1, 1932, the Southern Pacific had 25 grade separations in San Francisco County, six in San Mateo County, and four in Santa Clara County. Reports on the Peninsula Grade Crossing Conference are from *San Francisco Chronicle*, September 1, 1929, September 7, 1929, October 17, 1929, and February 22, 1931.

government supplemented the program in 1938 and 1939 with the Federal Aid Grade Crossings Appropriation and added further support in 1940 and 1941. While safety at grade crossings was an issue across the country, the federal government appropriated this funding mainly to stimulate employment during the Great Depression. A specified amount of the money had to be spent in metropolitan areas where projects were required to directly draw workers from the relief roles. Railroad company track mileage and Federal Aid Highway mileage also had to be taken into account when this funding was allocated to the states.

Even with over $12 million directed to California from 1935 to 1941 specifically for constructing railroad grade separations, there were still challenges in prioritizing which crossings would receive attention which left some dismayed as some of the more hazardous urban railroad grade crossings would not be alleviated because they were not on Federal Aid Highways or extensions of those highways. Conversely, not every grade crossing needed to be separated. The California Highway Commission found that before 1931, seventy percent of grade crossing accidents occurred at ten percent of the crossings and forty percent of accidents occurred at just three percent of the crossings. They also found that no accidents had occurred at sixty-seven percent of crossings. While clearly some grade crossings were more dangerous than others, some hazardous examples in urban areas proved to be simply too difficult and expensive to resolve with the funding available.[127] Over sixty-five railroad overheads and underpasses were built or upgraded in California through federal funding between 1935 and 1941. Almost all of this construction stopped during World War II when bridge construction was focused on military and war-time needs.

Following World War II, railroad grade separation construction continued, although at a slower pace than roadway grade separations. Demand for increased safety and a reduction of delays where railroads and highways intersected drove the continual removal of at-grade crossing across the state. More of the new railroad grade separation structures were built as overheads, passing over the railroad, than had been prior to the war. This decreased the complications of railroad coordination and funding participation. Highways, many of which were freeways, also needed to be wider with high vertical clearances than could be built with standard underpass technology. Overheads allowed the Division of Highways to choose the highway route with minimal assistance from and disturbance to the railroads. While in the 1930s, underpasses accounted for roughly two thirds of all railroad grade separations, by the mid-1950s overheads had come to account for half of all railroad grade separations and this percentage continued to rise. During that period, over seventy percent of railroad grade separations were along main or branch lines, with far fewer located along spur lines or other tracks. By the end of the decade, railroads

[127] George T. McCoy, "39 Grade Crossings on California Highways Being Eliminated with $7,500,000 Federal Funds," *California Highway and Public Works*, October 1935, 1-6; Biennial Report of the California Highway Commission, 1936, 76; F.W. Panhorst, "Sixty-Eight Grade Separation Projects Aggregate $11,000,000," *California Highway and Public Works*, May 1939, 11-14; and J.G. Hunter, "Program of Improving Grade Crossings in California By Elimination or Providing Additional Protection on a Comprehensive Plan Consistent with and Financed by Federal Appropriation," California Railroad Commission, Engineering Department, Transportation Division, June 1934, 6.

contributed to less than twenty percent of railroad grade separation projects as increasingly few of these structures constituted the removal of at-grade crossings.[128]

3.3.4.2. Highway Grade Separations and Interchanges

As discussed in Chapter 2, there was a growing demand for limited access highways in the state during the 1930s, culminating with the passage of legislation permitting freeways in 1939. One of the central tenets of freeway design, though not initially part of its legal definition, was the elimination of cross traffic and intersections. This required grade separations. Prior to the war construction of highway grade separations grew over 600 percent to over a hundred such structures in the state by 1941.

The vast postwar bridge construction program that accompanied highway and freeway construction of the period compelled the Division of Highways to develop new and innovative designs for separating flows of motor vehicle traffic. Most highway grade separations are either overcrossings, where county or city roads pass over state highways, or undercrossing, where county or city roads pass under highways. Where freeways met provided another engineering challenge. Engineers needed to provide safe and smooth transitions between freeways and between freeways and surface streets. There was a desire to reduce driver confusion at the confluence of freeways and a desire to decrease traveling distances between highways. To accomplish these goals the Bridge Department employed a variety of grade separation and interchange structures that included curving bridges, off and on ramps, and multi-level structures. The first four-level interchange structure was built at the intersection of the Hollywood, Arroyo Seco (Pasadena), and Harbor freeways in Los Angeles in 1949. Others soon followed. Multi-level structures were useful at locations were traffic volumes were expected to be high. They had no grade crossings and provided simple movements for vehicles with entrances and exits from the right side of the road. They also reduced the amount of right-of-way required for intersections on freeways and provided overall symmetry and uniformity. As the Tables 1 and 2 on page 61 indicates, the lion's share of bridge design and construction in California after World War II was devoted to separating highway traffic. By the early 1950s, engineers in the Division of Highways Bridge Department were allotting approximately eighty percent of their work to designing bridges for freeways including overcrossings, undercrossings, and interchanges.[129]

Interchanges were among the most important structures built within the burgeoning freeway system. Their designs were divided into two general categories: direct and indirect. Direct interchanges brought traffic from one roadway to another in the most direct fashion. They were used at the intersection of major freeways and often required multiple component structures. Indirect interchanges, such as cloverleaf style interchanges, had merging roadways that were

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[128] Division of Highways, *Fifth Annual Report*, 1952, 149; California Department of Public Works, Division of Highways, *Seventh Annual Report to the Governor of California by the Director of Public Works*, (Sacramento: California State Printing Office, 1954), 174; and Division of Highways, *Twelfth Annual Report*, 1959, 154-155.

[129] S. V. Cortelyou, "Four Level Grade Separation for Los Angeles Parkways Intersection, "*California Highways and Public Works,* May-June 1944, 9; "Free Flow of Traffic on or off Freeways Presents Many Problems," *California Highways and Public Works*, March-April 1945, 24-25; A.M. Nash, "Designs for Interchange of Traffic Streams," *California Highways and Public Works*, January 1947, 5; "Freeway Interchange," *California Highways and Public Works,* March-April 56, 30-31; Division of Highways, "Fifth Annual Report," January 1952, 139.

used in secondary freeways and expressways. With the novelty of freeway designs and the growing volumes of traffic at the time, engineers were challenged by how to construct appropriate interchanges. For instance, engineers struggled to comprehend and analyze traffic behavior, to better predict how the bridge structures that make up interchanges would be used and how they would provide safe and efficient traffic flows.

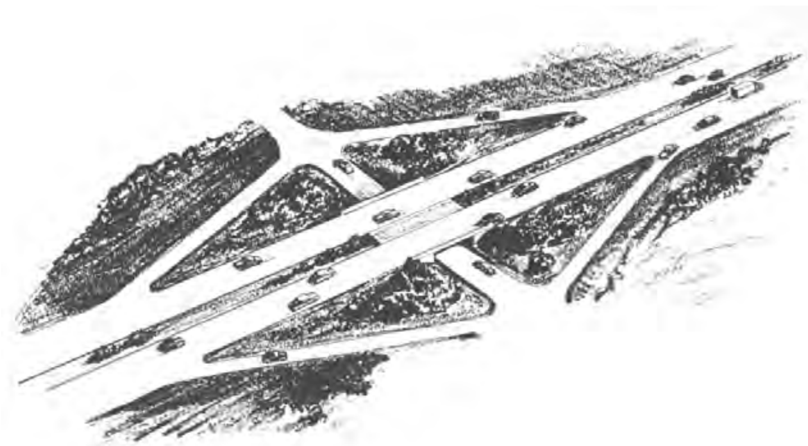

Figure 14: Diamond interchange design, 1951.

Interchange design choices depended not only on traffic volumes but also the setting, whether it be a tight urban right-of-way or less confined rural right-of-way. Designers also wanted to build structures that would convey the flowing nature of efficient movement and thus employed reinforced concrete for most highway grade separation and interchange structures. Interchange design grew as freeway design developed in the late 1940s and early 1950s. There were not only various cloverleaf style interchanges, but also other named interchange designs such as the diamond style design shown in Figure 14, or trumpet, rotary, and collector road designs. Many interchanges were hybrids and combinations of these forms. Various bridge types could be employed depending on the traffic volumes, required spans, and aesthetic appearance desired.[130]

[130] L.C. Hollister, "Careful Design Cuts Construction Costs on Los Angeles Freeway Structures," *Civil Engineering*, May 1950, 42-46; A.M. Nash, "Designs for Interchange of Traffic Streams," *California Highways and Public Works*, January 1947, 5; Sam Helwer, "Traffic Interchange Design," three part article, November / December 1950, 50-52 and 60; January / February 1951, 50-53; and March / April 1951, 50-54.

4. CONCLUSIONS AND REGISTRATION GUIDELINES

The period between 1936 and 1959 was one of enormous change and extensive construction within California's transportation system. Bridges continued to play their crucial role enhancing transportation development, supporting community planning and development, and contributing to the state's role in military history. Innovations helped the state become a national and international leader in bridge design and building. Understanding such national and state-wide trends is important in appreciating the historic context of individual bridges. Some of the state's bridges built in this period have important associations with national and statewide trends, whether in association with events and trends or association within the field of bridge engineering. Others, like most historic resources, are significant on the local level. Locally significant bridges must be shown to be importantly associated with significant local historic trends or events or are significant for their engineering, designer, or builder within a region.

Bridges in California are usually evaluated under two National Register criteria: Criterion A, for their role in local or regional history, especially their contribution as links within the transportation system, and Criterion C, relating to possible significance in the field of engineering. Bridges are infrequently, if ever, found to be significant under Criteria B or D. Important historic persons associated with bridges are usually involved with their design, thus making them significant under the "work of a master" clause of Criterion C. Historic structures, such as bridges, can occasionally be recognized for the important information they yield, or might yield, regarding historic construction materials or technologies, thus making them significant under Criterion D. Bridges in California built during this period, however, are extremely well documented, so they are not themselves principal sources of important information in this regard.

Under Criterion A, California highway bridges constructed between 1936 and 1959 are potentially significant if they are importantly associated with trends and/or events in transportation development, regional or local economic development, community planning or military history. Establishing this fact, though, should be done with certain principles in mind. Bridges, like other infrastructure, are inherently vital to communities as they are critical elements of essential city or regional planning, and they considerably impact communication and the distribution of people, goods, and services that facilitates development on both the local and regional levels. These common effects of bridge construction do not typically provide sufficient evidence to demonstrate how a structure may be deemed significant for its association with an important historic context; otherwise virtually any bridge would be shown to be important in this way. To be eligible for listing in the National Register, resource types such as bridges and other infrastructure must have demonstrable importance directly related to important historic events and trends, with emphasis given to specific demand for such facilities and the effects the structure had on social, economic, commercial, and industrial developments locally, regionally, or nationally. In this way, bridges may be significant as physical manifestations of important transportation and community planning developments on the local, regional, state, or national level. In this analysis, for example, a bridge that is the first in its location would be inherently more significant than one that is the second or third constructed at that location.

Under Criterion C, California highway bridges constructed between 1936 and 1959 are possibly significant for their importance within the field of bridge engineering and design. This significance derives from a bridge embodying distinctive characteristics of its type, period, or method of construction, or representing the work of a master engineer, designer, or builder. The historic significance of bridges within the field of bridge engineering and design has been studied in great detail in California and other states as a result of dozens of historic bridge inventories sponsored by the Federal Highway Administration during the 1970s, 1980s, and 1990s. While bridge types and inventory methods varied from state to state, the many historic bridge inventories have generally established salient attributes that help define significance of structures within the field of bridge engineering and design. These attributes are as follows:

- Rarity – the number of remaining examples of a bridge construction type;
- Innovative design techniques or use of construction methods that advanced the art and science of bridge engineering;
- Boldness of the engineering achievement – representing the measures taken to overcome imposing design and construction challenges related to load, stress, and other engineering and environmental complexities;
- Aesthetics – the visual quality achieved in a bridge's individual design or with its appropriateness within the natural or man-made setting.

These attributes are weighed in conjunction with evaluation of a bridge's type, period, or method of construction and its association with possible historically significant engineers and/or builders.

In order to be listed in the National Register, a bridge must have both historical or engineering significance as well as historic integrity. Loss of integrity, if sufficiently great, will overwhelm the historical significance a bridge may possess and render it ineligible. Likewise, a bridge can have complete integrity, but if it lacks significance, it must also be considered ineligible. Integrity is determined through applying seven factors defined by National Register guidelines. Those factors are location, design, setting, workmanship, materials, feeling, and association. These seven can be roughly grouped into three types of integrity considerations. Location and setting relate to the relationship between the property and its environment. Design, materials, and workmanship, as they apply to historic bridges, relate to construction methods and engineering details. Feeling and association are the least objective of the seven criteria and pertain to the overall ability of the property to convey a sense of the historical time and place in which it was constructed.

As discussed in Chapter 1, bridges can also be found eligible for listing in the National Register as contributors to historic districts. The potential for a bridge to be a contributor to a historic district depends on its relationship with the same historical associations or architectural characteristics that make significant either adjacent properties or other bridges in its vicinity. Bridges may also be eligible for listing in the National Register as part of historic landscapes.

The following section provides guidelines for identifying and evaluating bridge types and construction methods that were either new or innovative during the period 1936 to 1959: welded steel bridges; Bailey trusses; concrete box girders; prestressed concrete; and freeway interchanges. As these are issues of bridge engineering and design, this guidance will be useful in addressing significance under Criterion C. The section includes both the characteristics that may qualify a bridge for listing in the National Register and the thresholds of significance that could be used to categorize bridges as ineligible for listing in the National Register. Most of these bridge types and construction methods have specific time periods in which they were developed, initially implemented, and used in wider application. They all represent some sort of bridge engineering innovation that permitted longer spans, greater loads, quicker construction, and/or cost savings. Many also resulted in bridges with new aesthetic qualities. As is true with any resource type, many bridges are associated with the new or innovative bridge types and construction techniques of the period, but not all are or will be significant for listing in the National Register. This section attempts clarify which bridges may be eligible as well as qualify some factors that constrain the number of bridges that may be eligible for listing in the National Register.

4.1. Qualifying Characteristics and Ineligibility Thresholds of New Types and Innovative Techniques

4.1.1. Welded Steel Bridges

Welding was used in a variety of steel bridges during the 1930s, 1940s, and 1950s. Initially, it was largely used to repair structures and sporadically, during the 1930s and 1940s, for entire bridges. By the early 1940s, welding techniques and applications had largely been perfected and included implementation of X-ray analysis and other radiographic techniques to detect internal cracks, but the lack of bridge construction during World War II delayed its wide implementation. The Division of Highways increased its use of welding for large components of structures and for entire bridges during the late 1940s and early 1950s. Welding was most often used on steel girder bridges and steel trusses. Welding combined interconnected elements so that they could be calculated together for stress and load. It permitted steel structures to be lighter, constructed with less steel, and improved the strength of steel structures allowing for longer spans and greater loads than standard steel. It also provided cost savings and contributed to enhancing the aesthetic quality of steel members in bridges.

Characteristics of a welded structure, with large welded components or comprised of all welded components, that may qualify it for listing in the National Register are its age, its degree of innovation, its boldness of application, and its contribution to the overall aesthetics of the bridge. There are likely few early examples of welded bridges from 1930s and 1940s. Some rare example may have been noted as successful applications of the then promising technology. Others may be where the Division of Highways used innovative techniques to accomplish bold welded designs. These innovations may have been required to construct bridges on large spans, skews, curves, and for great loads. Standard rolled beams, for instance, were three feet wide in the early 1950s, but welding may have allowed the Division of Highways to construct wider girders and thus achieve longer spans for greater loads. Welding may also have contributed to the clean lines and smooth appearance that was admired in mid-20th century steel structures, thus playing an important role in a bridge's aesthetic quality.

The first threshold of ineligibility, based on the significance a welded structure may have, is the amount of welding that was used for the structure. In early applications in particular, welding was used to repair structures or to strengthen portions of steel bridges. While such applications were necessary within the development of welding in bridge construction, they do not in general provide the significant quality that would exhibit this technology in an important way. The second threshold of ineligibility is one of age, innovation, and boldness. As welding became more common in the 1950s, it was used on a variety of bridges. The larger the bridge, the more innovative the welding needed to be to achieve bold design overcoming stress and load design challenges. Thus, welded bridges from the mid to late 1950s are less likely to have been constructed with innovative techniques to achieve bold designs. The third ineligibility threshold is that welding is unlikely to be the central factor in whether a structure achieves significance for its aesthetic qualities. Welding has to be taken into account with other aesthetic qualities including the combined elements of the entire bridge's structure as well as the visual quality of the structure within its surrounding environment.

4.1.2. Bailey Trusses

Bailey trusses were invented during World War II to provide easily constructed bridges on which the military could move heavy tanks. The ease and durability of the structure made them popular for quick construction following the war, particularly as they were readily available as postwar military surplus. The trusses were interchangeable pre-fabricated steel components and were highly versatile. Bailey bridges could be assembled in seven different configurations up to three panels wide and two panels (double-story) in height, with each successive set of panels increasing structural strength. As described in Chapter 3, installation of multiple panels on longer spans also increased the load capabilities of these trusses.

This type of bridge is inherently rare in California because the state was generally able to quickly construct permanent bridges all across the state. Thus the single greatest characteristic of Bailey truss bridges that may qualify them for listing in the National Register is age. Examples from the immediate post-World War II period likely best represent the significance of this bridge type. The truss's design qualities are less significant because Bailey bridges are formed from standard size components that were combined to carry greater loads and cross longer spans. Larger size Bailey bridges do, to some extent, exhibit greater engineering achievements than shorter spans. The innovation of this bridge type is in its versatility and ease of construction. The aesthetic quality of Bailey bridges is relatively low compared with other metal bridges as they do not achieve the same visual qualities of the neat and fine etched lines of larger trusses or the clean crisp powerful lines of steel girders. Rather the aesthetic value of a Bailey, modest as it may be, may be in its appropriateness within its environmental setting.

Thresholds of ineligibility for Bailey trusses are likely quite low. Although they are relatively rare as a truss type in California, their significance within the field of engineering is based on their versatility and ease of construction rather than any inherent innovative or bold engineering quality. Later examples are likely less representative than earlier versions. Length of span and truss configuration may also provide added levels of importance showing the capabilities of the truss type. Thus a double story triple truss example exhibits greater engineering qualities than a single story single truss example may. The size and configuration of a Bailey truss will also contribute to its overall visual appearance and aesthetic significance. Like many bridge types, aesthetics play a minor role in the evaluation of this bridge type.

4.1.3. Reinforced Concrete Box Girders

The Division of Highways began building reinforced concrete box girder bridges in 1937 and 1938. By the early 1950s, they were among the standard selection of bridge types that could be used, many of which were used along freeways. The type was innovative because it provided designers greater flexibility and contributed to cost savings. With shallower girders than standard reinforced concrete, engineers needed less concrete for stronger bridges and had enhanced abilities to build skew or curved bridges. The girder shallowness was useful in providing adequate clearance at waterways, railroads, or highways while not requiring sharp increases in deck grade or requiring long approaches. Designers could also provide longer unsupported spans to better respond to environmental or project related challenges. In addition to their physical design capabilities, the concrete box girder provided a new aesthetic quality that, at best, expressed the minimal and graceful qualities of Modernism. Concrete box girders helped emphasize the strength and monolithic character of reinforced concrete.

The characteristics that may qualify a concrete box girder bridge for listing in the National Register are its age, its degree of innovation, its boldness of application, and the overall aesthetic of the bridge. The pioneering examples of concrete box girder bridges range from the late 1930s to the early 1950s, though some design innovations continued through the 1950s. Design innovations include the shallowness of girders, the bridge skew and/or curve, and its integration with the roadway. Bold engineering qualities include longer spans, up to 200 feet (60 meters) by the late 1950s, high vertical clearance, and swooping curves that permitted smooth roadways and kept the bridge in smaller right-of-way than might otherwise been needed. Unlike many other bridge types, aesthetics could play a distinctive role in the significance of some bridges. One needs to examine both the inherent visual qualities of structures themselves and the visual qualities of concrete girder bridges within their environmental setting. As described above, the Division of Highways engineers attempted to further decrease the appearance of the girder depth and enhance the type's overall form with such features as rounded corners at the girders, cantilevered overhangs, tapered piers, and slender curved railings. Concrete box girder construction in both standard reinforced concrete and prestressed concrete became the most abundant type of concrete bridge in California built during the height of the freeway era in the 1960s and early 1970s.

The thresholds of ineligibility for concrete box girders are based on the age of such a structure, its innovation of construction, and the boldness of the application of design. By the late 1950s, the Division of Highways defined the depth span ratio for simple span concrete box girders at 0.060 and 0.055 for continuous spans. Thus a one hundred foot span ideally could have been designed with a six foot simple span or a five and a half foot continuous span. Less innovative examples of concrete box girder will have higher depth span ratios. Less innovative examples did not require those bridges to be built on a skew or be built with a curve. Similarly, longer spans generally represent bolder engineering achievement, but environmental and project related challenges should also be taken into account when assessing a concrete box girders engineering achievement. Spans under 80 feet, for instance, could easily have been built with other bridge types, such as tee beam, and thus constitute less of a bold engineering achievement. In addition, it is important to examine the visual qualities of concrete box girders. Less important examples will likely be simple box shapes with straight piers and look very much like standard reinforced concrete.[131]

4.1.4. Prestressed Concrete Bridges

The Division of Highways introduced prestressed concrete to California in 1951 and slowly adopted it for wider use throughout the decade. It was used in slabs, girders, tee beams, and box girder bridges, many of which were built along freeways. A majority of these structures were built using pre-cast methods, but some required cast-in-place methods. The Division of Highways experimented with a variety of prestressed concrete forms, designs, and techniques during the 1950s and began to standardize prestressed concrete bridge types in 1958. Thus, most prestressed concrete bridges from the early to mid-1950s were built during the pioneering period of this material within California. The characteristics that may qualify a prestressed concrete bridge from this period for listing in the National Register is its conveyance of the material's design innovation and the bold application of the material, taking into account the challenges facing the bridge designer. Similar to innovations associated with concrete box girders, prestressed concrete bridges could be constructed with greater strength and longer spans than other concrete types. It could be built with shallower depth than reinforced concrete and was easily designed for skew structures or for curves. It allowed for higher vertical clearances and flatter deck approaches than even concrete box girders. Like standard reinforced concrete box girders, aesthetics could play a distinctive role in the significance of some prestressed concrete bridges. One needs to examine both the inherent visual qualities of structures themselves and the visual qualities of the bridges within their environmental setting. With the various designs, the Division of Highways engineers used this material in part to achieve the visual qualities important in mid-20th century Modernism including efficiency, harmony, balance, as well as material and functional honesty.

The eligibility threshold for prestressed concrete bridges from the 1950s depends on their ability to convey the engineering significance of the material. This includes those structures representing innovative types and techniques that were either supplanted by improved methods or found to be successful and implemented widely. Significant prestressed concrete bridges are likely not to include those structures from the 1950s that were built with only some prestressed concrete components. Prestressed structures from the late 1950s are less likely representative of variety of designs that the Division of Highways used before prestressed concrete bridges began to be standardized. Less significant examples will not exhibit the material's important design qualities such as its ability to be constructed with a low depth to span ratio, its use for curved and skewed bridges, and its use in long spans with high vertical clearance and flat deck approaches. Less significant examples will also not exhibit the slender and graceful qualities that were made possible with this material, resembling standard reinforced concrete instead.

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[131] Department of Public Works, Division of Highways – Bridge Department, *Bridge Planning and Design Manual*, Vol. 2, 1955-1966 (revised January 1961), 5.7.0.

4.1.5. Freeway Interchanges

During the late 1930s and throughout the 1940s and 1950s, the Division of Highways built hundreds of miles of freeway requiring hundreds of bridge structures at overcrossings, undercrossings, and interchanges. As a new type of highway design, Bridge Department engineers worked through many of the design challenges during this early period of freeway construction in California. Interchanges were considered to be one of the most important elements of freeway design. Overcrossings and undercrossings, i.e. roadway grade separations, were often built as single or double bridge structures taking county or city roads either over or under state highways. Their designs can largely be viewed by their material and bridge type, discussed elsewhere in this report. Interchange structures, though, are more complex than most bridge designs and were a new structure type built during the early freeway period. Although comprised of individual bridge structures, interchanges were built as systems to provide safe and efficient flows of traffic between freeways and between freeways and surface streets.

The characteristics of freeways constructed during this period that may qualify it for listing in the National Register center around the innovation and complexity of design as well as the aesthetic success demonstrating the movement and efficiency promised by freeway interchange design at that time. Early examples of important structural configurations naturally take on a measure of significance above subsequent examples, but later examples may demonstrate innovative uses of component bridge types providing higher levels of service for increasingly complex intersections of freeways and local streets. Research into the significance of structures may indicate the design choice made to manage the expected traffic and subsequent traffic evaluations may measure the success or innovation of those design choices. Aesthetics too plays a role in the significance of interchange design, as engineers of the period considered the visual appearance of interchanges to be important. With these complex structures, they wished to convey the efficient flow of traffic with simple and fluid lines inherent in Modern design of the period.

As there were hundreds of miles of freeways built during the 1940s and 1950s, inevitably a great many freeway interchange structures were built to move traffic from one freeway to another and move traffic on and off freeways from local streets. Eligibility thresholds for freeway changes are likely very high. Not only are there many examples of these structure, but many are built in a simple manner that are not much more complex than most bridges. The eligibility thresholds for freeway interchanges are based on the complexity and innovativeness of design as well, in part, on the age of the structure. Less significant freeway interchanges will be those that were standard designs, such as cloverleaf or diamond types. These designs were relatively simple and were often built in repetitive fashion throughout a freeway project. Less significant examples also will not represent innovation in interchange design, as may be indicated in the design choices made for the specific location, though they may contain some new bridge types for the period such as a bridge built in prestressed concrete. Finally, less significant examples also will not exhibit aesthetic qualities that emphasize efficient traffic flow.

4.2. Conclusion

This report was prepared to establish the historic significance of roadway bridges built in California between 1936 and 1959, providing a basis for the consideration of these bridges to be listed in the National Register of Historic Places. Although there were several new bridge types and innovative methods used during this period, many bridges were constructed using well understood technologies and techniques. The thousands of bridges built from this time period are testimony to the vast economic and population shifts of the mid-20th century in California, and as is supported by this document, at least a small group of those structures could meet the criteria for listing in the National Register of Historic Places.

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APPENDIX A:

TUNNELS

TUNNELS BUILT IN CALIFORNIA BETWEEN 1936 AND 1959

The following discussion addresses the context for tunnel design and construction during the time period addressed by this overview, 1936 through 1959. It is included here because Caltrans lists tunnels as structures in its bridge list. Of course, bridges and tunnels share little common in terms of design and materials.

The West, and California in particular, has led the nation in utilizing tunnels to carry roads, highways, and freeways through regions difficult to otherwise traverse. The earliest highway tunnel built in the United States was in 1870 went through a rock cliff in San Francisco. Tunnel locations in California during the late 19th and 20th centuries included rolling hills, large metropolitan locales, as well as in rugged mountainous terrain. By 1936, there were 14 tunnels in place built under the auspices of the Bridge Engineer's Office of the Division of Highways in California. Between 1936 and 1959, the Division of Highways was involved with some major tunnels constructed to carry highways and freeways through both mountains and cities, all built with reinforced concrete linings. Some were built in response to other structures in urban areas, others were the result of the need to open up easier access to parts of the state for economic and recreational purposes as the state's population grew.[132]

Although tunnels were complicated and sometimes dangerous to construct, there were economic and safety advantages to building tunnels rather than open cut roads. Tunnels could be carved in straight alignments eliminating the need for curving highways in hilly or mountainous areas. Tunnels also eliminated the need for snow removal, and they contributed to low cost maintenance. Where possible, the tunnel designers and construction workers attempted to blend the tunnels into their surroundings. Though tunnels were considered to be an acceptable option, taking into account both safety and economics, the cost of ventilation and lighting added two additional factors not otherwise required. Lighting was necessary and had to be perfectly calibrated so as to make it safe for drivers to come in and out, day or night, with little or no problems adjusting to natural illumination. Engineers had to determine the proper amount of artificial lighting to use in tunnels to combat daylight brightness while at the same time install lighting that would automatically dim to give proper lighting for nighttime driving.[133]

Conversely, there was at least one situation during this period where the Division of Highways abandoned an earlier tunnel for a newly constructed surface highway. The Newhall Tunnel had been built in 1910 to accommodate travelers going back and forth between Los Angeles and the Mojave, Owens, and San Joaquin Valleys. During the 1930s, the tunnel became a traffic bottleneck as population increased in the area. A three lane highway through nearby Weldon Canyon eased the problem for a short time. However, by 1940, over 4000 cars per day and thousands more on the weekend traveled this highway and this situation continued to plague the

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[132] Federal Highway Administration, *America's Highways 1776-1976,* 442; Division of Highways, *Tenth Biennial Report,*1936, 72-74. Note: Most of these 14 tunnels were located in Ventura and Los Angeles counties.
[133] Regional Office, United States Bureau of Public Roads, "Highway Tunnels in Western States," *Public Roads*, July 1937, 125-150; Roy Matthews, "Tunnel Illumination: Gaviota Gorge Project Develops New Ideas," *California Highways and Public Works,* November-December 1953, 37, 59.

road with delays. The state did away with the tunnel and replaced it with a wide, divided highway.[134]

A majority of California's extant tunnels were constructed before World War II, with most built during the 1930s. Only a third of tunnels in the state date to the latter half of the 20th century. Most of the existing tunnels constructed between 1936 and 1959 are located in either the San Francisco Bay Area or in Los Angeles County with only a few others elsewhere in the state.

The Waldo Tunnel, part of the northern approach to the Golden Gate Bridge, is a good example of this type of structure built during the 1930s. The tunnel was a necessary component of the highway project associated with the Golden Gate Bridge and was a major engineering undertaking. The Division of Highways planned construction of a highway north of the new Golden Gate Bridge to manage the expected increase in traffic. The highway connected the Redwood Highway (State Route No. 1 and U.S. Highway 101) with San Francisco and required a 1000 foot long tunnel through the unstable mountainside near Sausalito. The Division of Highways not only wanted to have the northern highway approach to the Golden Gate Bridge avoid the town of Sausalito, but also assessed that the area was close to an earthquake fault which would have made heavy cuts and fills unacceptably unpredictable. Construction of the tunnel was not only considered to be safer, but also quicker for motorists. With over 50,000 cubic yards of material excavated from the 29 foot tall four lane tunnel, the structure, completed in 1937, was one of the largest undertaken by the Division of Highways at that time.[135] By the 1950s, the number of automobiles traveling this way increased to almost 14 million in a year, eight times the number which passed the same way in 1937. This required the Waldo Approach to be widened and required a second tunnel to carry the northbound traffic. The project called for the reconditioning of the old tunnel and the construction of a new 1000 foot long tunnel. The Division of Highways widened the roadway to three lanes in each direction and designated it as a freeway in 1947. Thousands of cubic yards of material excavated to build the tunnel became the eastern embankment. The second tunnel opened in March 1956.[136]

One of the most difficult undertakings in tunnel construction during the 1940s and early 1950s was done as part of the Angeles Crest Highway. Located in the Angeles National Forest, this project took over fifteen years to complete, with work beginning in 1941 interrupted by World War II. Excavation on two tunnels had already started and over sixty miles of roadway had been completed when work stopped. The project resumed in 1946 and was mostly built with prison labor and state workers. The two tunnels, 680 feet and 470 feet respectively, were blasted through the solid rock of Mount Williamson requiring eighteen inch reinforced concrete lining. When finally completed in November 1956, the Angeles Crest Highway, along with its tunnels,

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[134] John D. Gallagher, "Newhall Tunnel Replaced by Cut," *California Highways and Public Works,* January 1940, 16-18, 24.

[135] Jno. H. Skeggs, "Waldo Approach An Engineering Feature of Golden Gate Bridge," *California Highways and Public Works*, June 1937, 16; Jno. H. Skeggs, "Grading Marin Approach to Gate Bridge Nears Completion on Schedule," *California Highways and Public Works*, January 1937, 2-3,9; Jno. H. Skeggs, "Marin Approach to Golden Gate Bridge Involves Tunnel and Record Grading Job," *California Highways and Public Works,* May 1936, 6-7, 26.

[136] Drury Elder, "Waldo Project: Golden Gate Bridge Approach Widening Is Urgently Needed," *California Highways and Public Works*, July-August 1953, 8-10; and "Waldo Project: Golden Gate Bridge Freeway is Opened," *California Highways and Public Works*, March-April 1956, 19-21.

provided access to recreational areas that heretofore could not be reached without great difficulty and shortened the trip from Los Angeles to Big Pines, east of Mount Williamson, by 43 miles. Much of the materials blasted from the construction site were reused in the Angeles Crest project. At the worksite, rock residue was used to construct needed culverts and portal facings. Concrete also came from the blasted material and mixed on site, as transportation was too costly and sometimes virtually impossible. The trees felled there were treated at a sawmill moved from the California Institute for Men Chino and rebuilt on the site and used in the project or by local residents.[137][138]

In San Francisco, tunnels continued to be built to enhance access to various parts of the hilly city. The Broadway Tunnel, started in 1950 and completed in 1953, provided a link between the north areas and approaches to the Golden Gate Bridge and the city's business district. Soon after its completion, the tunnel carried 17,000 vehicles per week.[139]

By the late 1940s, the Gaviota Pass in Santa Barbara County had become the site of "one of the most tortuous stretches of U.S. Highway 101 between Los Angeles and San Francisco."[140] Widening the road with a cut would have required the disposal of over 400,000 cubic yards of material. Thus the Division of Highways decided to construct a 400 foot long tunnel for northbound traffic instead. Construction began in November 1951 and was completed in March 1952. This quick construction schedule necessitated around the clock work so as to alleviate any conflict with passing traffic.[141] As was the case with other tunnels constructed during this period, designers tried to align the portal design with the natural setting taking into account native plants and shrubs for adjacent landscaping.[142]

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[137] J.M. Lackey, "Two Mountain Tunnels Necessary On The Angeles Crest Highway," *California Highways and Public Works*, March 1941, 28-31; and John Ritter, "On Angeles Crest: Work on Recreation Highway is Resumed," 6-7, *California Highways and Public Works*, September-October 1948, 44.

[138] J.M. Lackey, "Two Mountain Tunnels Necessary On The Angeles Crest Highway," 28-31; G. A. Tilton, Jr., "Boring 2 Tunnels on Angeles Crest Highway," *California Highways and Public Works,* Dec 1941, 8-9, 16; **"**Angeles Crest Highway Construction Stopped as Unessential to War Effort," *California Highways and Public Works*, December 1942, 18-19; John Ritter, "On Angeles Crest: Work on Recreation Highway is Resumed," 6-7, 44; and George Langsner, "Angeles Crest Highway Opened: Half Century Dream of Engineers Realized," *California Highways and Public Works,* November-December 1956, 1-17.

[139] "New Broadway Tunnel in San Francisco: Bay Region's Ninth Underground Traffic Facility," *Motorland*, May 1953, 13-15.

[140] J. E. Eckhardt, **"**Gaviota Pass: Tunnel Work to Provide 4-Lane Highway Under Way," *California Highways and Public Works,* November-December 1951, 36.

[141]Eckhardt**, "**Gaviota Pass," 36-37; John E. Witte, "Gaviota Tunnel: Limited Access Freeway Section on U. S. 99 Is Nearing Completion," *California Highways and Public Works*, January-February 1953, 10-14, 38.

[142]Eckhardt**, "**Gaviota Pass, 36-37.

ERRATA

JRP Historical Consulting. "Historic Context Statement for Roadway Bridges in California: 1936 to 1959." Prepared for Caltrans, January 2003.

Page	Correction
53	Report states that the "first prestressed concrete bridge constructed in the United States was erected at Walnut Lane in Fairmont Park, Philadelphia, Pennsylvania in 1949." This statement is only partially true. The Walnut Lane bridge was started in 1949, but not opened to traffic until 1951. The Tennessee Department of Transportation claims to have built and opened to traffic the first prestressed concrete bridge in the United States in 1950. This structure, over Duffy's Creek on Christmasville Road in Madison County, is a small three span bridge built with segmental prestressed concrete units. The Walnut Lane bridge is much larger and is thus the first major prestressed concrete bridge built in the country. In addition, the Oregon Department of Transportation and federal Bureau of Public Roads designed and built the Rogue River at Gold Beach in 1932 using Eugene Fresyssinet's prestressing method of decentering and stress control for the concrete arch structure. This method did not specifically place the reinforcing rods in tension like later prestressing methods. Reference: Bennett, R.M., Hufstetler, M.L., and Carver, M., "50 Year Old Prestressed Segmental Concrete Bridges." *Journal of Professional Issues in Engineering Education and Practice, American Society of Civil Engineers*, 128(2)(2002), 83-87; and Robert W. Harlow. "Oregon's Isaac Lee Patterson Memorial Bridge: The First Use of the Freyssinet Method of Concrete Arch Construction in the United States, 1932." *IA: The Journal of the Society for Industrial Archeology*. Vol. 16, no. 2, 1990.
59	Report states that no covered bridges were built in California between 1936 and 1959. There were at least two covered bridges built during this period in the state. The Bertha's Ranch Road Bridge (04C0047) and the Zane's Ranch Road Bridge (04C0048) were built in 1936 in Humboldt County approximately five miles south of Eureka.