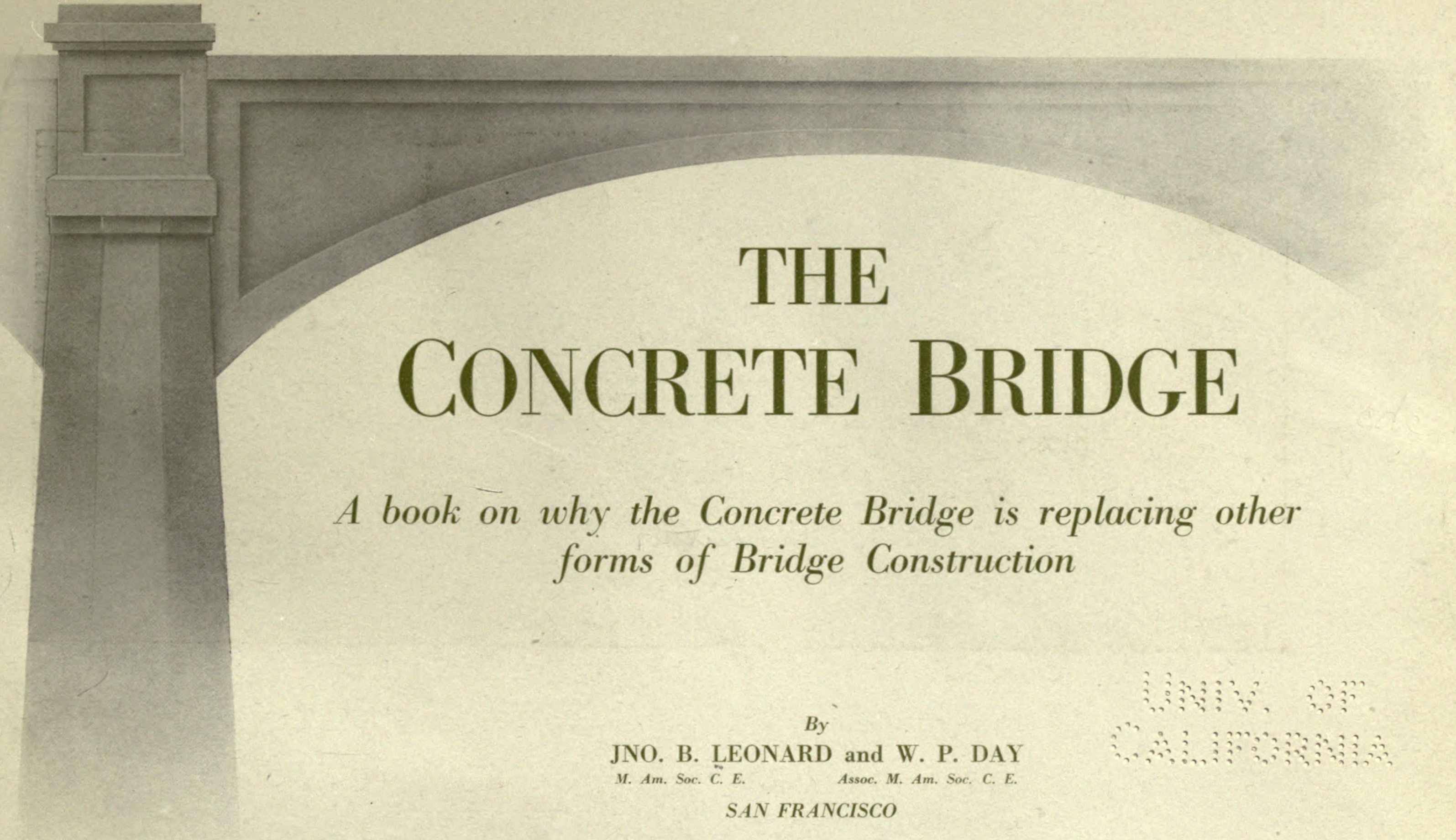
The Concrete Bridge

How it has Proved itself In California

The Bridge



THE CONCRETE BRIDGE

A book on why the Concrete Bridge is replacing other forms of Bridge Construction

By

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PREFACE

The purpose of this publication is to supply information as to the vast strides made in California during the past few years in the use of reinforced concrete for permanent bridge construction. It is believed that there exists in the minds of the public a limited understanding of what has been accomplished in this direction. A strong conviction is growing to-day, however, in favor of the desirability of structures of this character, due to the satisfaction given by those in existence.

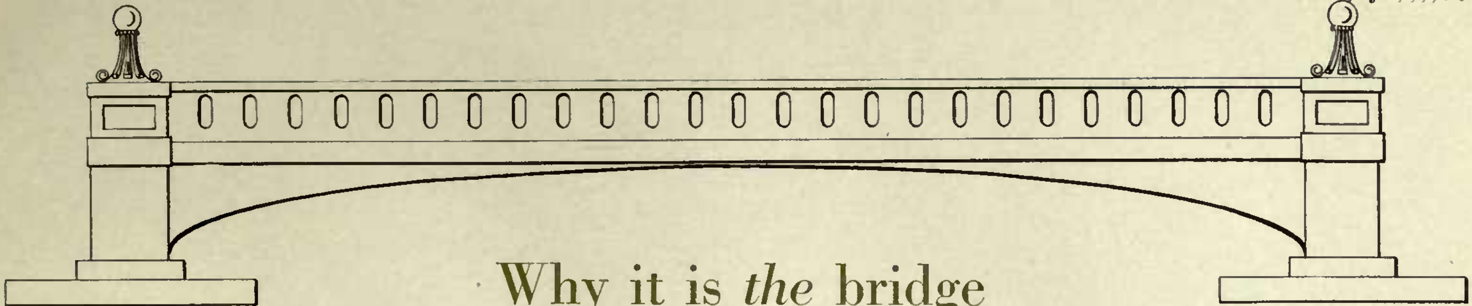
The publishers realize that they have only touched briefly upon the subject. Through their connection with all of the work shown herein, they are in possession of detailed knowledge of both the design and construction of each. They invite and will cheerfully answer any inquiries addressed to them for further information.

JNO. B. LEONARD.
W. P. DAY.

February 20, 1913.
528-530 Rialto Building,
San Francisco, California.

Gift of John B. Leonard

"Conformity with environment, economic use of material, pleasing outline and appropriate use of ornament make toward beautiful bridges, which are a sure indication of a progressive community."



Why it is *the* bridge

THE USE OF REINFORCED CONCRETE for the construction of bridges, in the State of California, has increased during the last few years in a very marked degree. With the advance in scientific information as to the action of steel and concrete in supporting loads, designers and builders have advanced, step by step, until today long spans and important structures are entirely feasible in the hands of competent engineers and constructors. As a result, many highway bridges throughout the State are built of reinforced concrete, this type taking the place of the old combination structures of steel and timber. Nor is the use of the material in this State confined to highway bridges. There are a few carrying heavy interurban cars, and the largest and heaviest locomotives.

In general, there are two types of reinforced concrete bridges—the flat span and the arched span. Each type lends itself to variation, in accordance with the ideas of the designer. The flat span is sometimes built without girders, more often with girders running the long way of the span. The arched span is sometimes built as a continuous arch with side walls and earth roadway. Occasionally the side walls are omitted, and the roadway is carried on columns resting on the arch. The arch is not always the full width of the bridge, the width being made up of two or more individual arches with a light floor between.

It is interesting to know that reinforced concrete construction tends toward the use of our home products. Timber for temporary supports and moulding forms is easily obtained on our own coast; cement and reinforcing steel are manufactured in our own State; sand and gravel are obtained usually on the site of the bridge, or at least not very far away; our rock quarries produce an abundance of crushed rock, where it is desirable to use this material. Annoying delays that often occur in the building of steel bridges are avoided by reason of the fact that cement and reinforcing steel are manufactured in California.

Methods of construction vary, of course, with the design and the location. Forms and temporary supports for flat span bridges offer no particular difficulty. Temporary supports—generally called falsework—for arches must be carefully designed and executed. Usually there is water under the arch, and piles are driven to carry the posts of the falsework. The proper time to begin construction is the low water period. This gives the contractor ample time during the spring season to place his plant on the site, and make general preparation for the work. Extreme care should be used in the proportioning of the concrete mixture, as well as in the method of casting. The ideal arch is that in which the work is carried on so continuously, that no joints occur as a result of the previous work drying out before the next can take hold, and yet not so fast but that the regular shrinkage in setting has been allowed for. Contractors usually prefer to cast side walls before removing the falsework, but this is apt to produce cracking in the walls, which, while not dangerous, is unsightly. The proper method is to allow the arch to take its natural form before casting the walls. All arches drop at the crown when the falsework is removed, owing to the compression of the arch under its own weight. The probable drop at the crown may be very closely calculated and allowed for in the forms, in addition to the allowance for the compression of the falsework timbers.

The element of cost is naturally of first importance to the prospective builder, and is worthy of careful consideration. In the first place, it is generally understood that a concrete bridge is more costly than a steel bridge. This statement needs explanation in order to convey the truth. It so happens that a concrete bridge may be cheaper than a steel one, depending entirely upon the live or moving load. For example, it is cheaper to build a reinforced concrete bridge, to carry locomotive and train loads, than it is to build a steel bridge for the same loads. On the other hand, a light highway bridge of steel with timber floor is cheaper than a concrete one. Concrete bridges are so heavy in themselves that the addition of a heavy live load does not materially alter their design. With the steel bridge, the live load is the all important factor, a heavy live load necessitating a very much heavier structure, as well as more costly. Concrete bridges designed to carry locomotive loads are at least 15 per cent cheaper than steel bridges designed for the same loading. The only type of steel highway bridge that is cheaper than a concrete bridge is that with a timber floor. Timber floors wear rapidly and must be replaced about once in three years, depending, of course, on the traffic. Under the usual conditions, if a steel bridge be built with a solid concrete floor to avoid the replacing of the timber, the cost of the structure will equal that of a concrete bridge. It is a well-known fact that all steel bridges must be painted periodically in order to preserve them. It is equally well known that after forty or fifty years at the most, the steel has deteriorated to such an extent as to make replacement of the structure a necessity. It must be borne in mind, also, that county bridges will not last as long as railroad bridges, because the former are not given the same care as the latter. It may be seen, therefore, that steel bridges require maintenance, and that further, they have a limited existence. Concrete bridges require absolutely no maintenance, and the effect of age is to strengthen rather than weaken.

From the foregoing, it is manifestly impossible to set a definite ratio of cost between a concrete and steel bridge. Cost is always a question of locality, of availability of materials, and of the foundations, all of which vary in each case. Steel bridges are sometimes, in fact often, built on cylinder piers, which cannot compare as supports with the solid piers used for concrete bridges. Assuming, however, that a concrete highway structure for a given locality can be built for $100,000, we may safely say that, ordinarily, a steel bridge, with timber floor, can be built for $85,000, and that its life, with proper maintenance, is fifty years. On this basis the annual charge for the steel bridge would be about as follows:

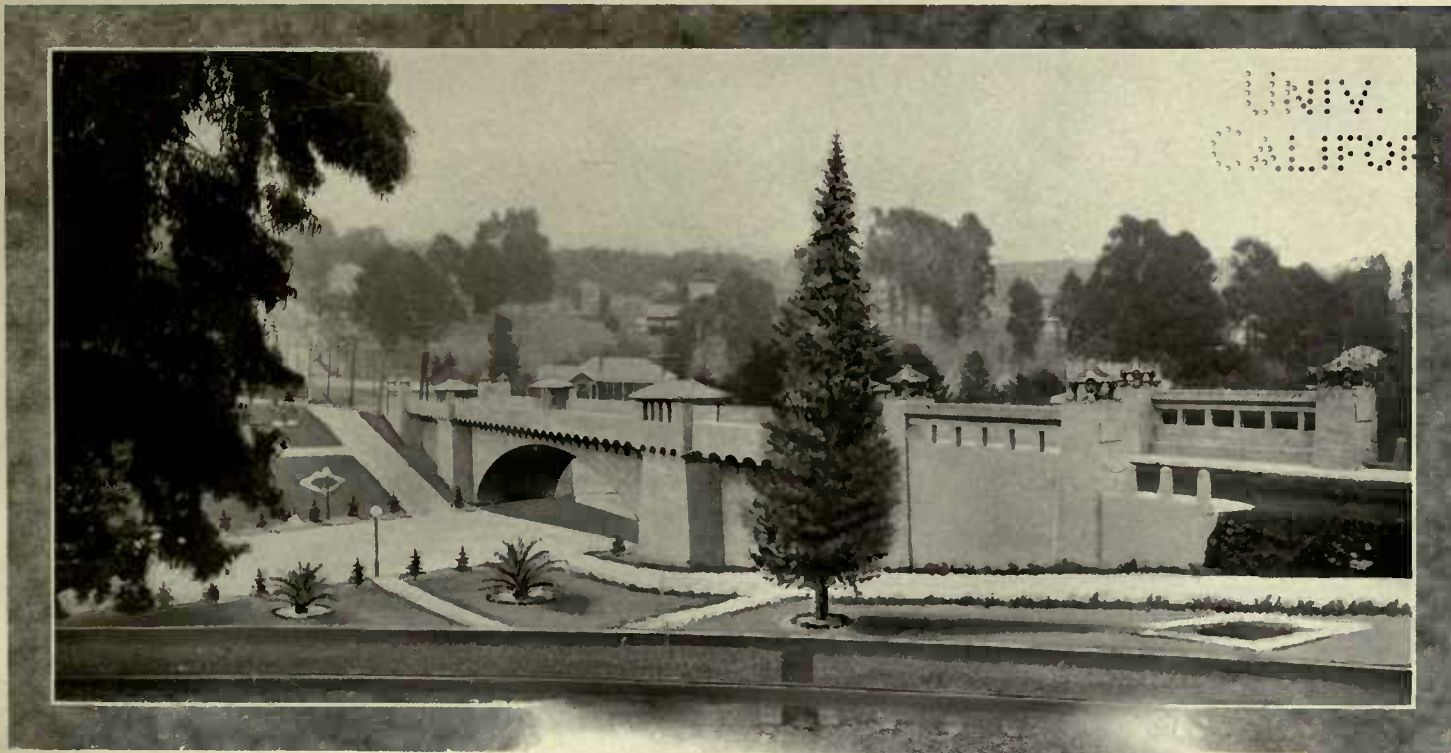
Average annual charge for repainting, assuming the bridge is painted once in 5 years at a cost of $3,000	$ 600.00
Average annual charge for renewing floor	400.00
Annual interest charge at 4 per cent on the investment	3,400.00
Annual sinking fund for renewal at end of 50 years at 4 per cent compounded	556.75
Total annual charge	$4,956.75

The only charge against the concrete bridge is the annual interest on the investment, which, at 4 per cent, amounts to $4,000, or a net saving of $956.75 per year in favor of the concrete bridge.

In addition to the advantage shown in the preceding, in favor of the concrete bridge, there is the artistic difference between the two, for which no monetary value may be assigned. The artistic side of bridge building has been given less attention than its importance warrants. Concrete lends itself beautifully to this phase of design. The Oakland Avenue Bridge, shown on pages 12-13, was designed with a view to pleasing appearance, and exemplifies the ability of concrete to meet this condition.

Showing the possibility for artistic treatment and suggestive of the adaptability of reinforced concrete for city, suburban or park bridges

Portals Oakland Avenue Bridge
Piedmont, California



Practical and picturesque, this bridge is an excellent example of ornamental concrete construction and its power to enhance the natural surroundings

Oakland Avenue Bridge
Piedmont, California

CLEAR SPAN OF 130 FEET
LENGTH OVER ALL 363 FEET
ROADWAY 22 FEET WITH
TWO 6 FOOT OVERHANGING SIDEWALKS
BUILT 1911

A happy combination of Mission architecture and modern engineering ideas, this bridge, with its [illegible] heavy grade, involved many problems in its construction

A view of approach, showing ornamental kiosk
Oakland Avenue Bridge
Piedmont, California

Note the pleasing spring of the arch, which rises [illegible] feet [illegible]. A simple yet impressive structure

Dry Creek Bridge
Stanislaus County, California

CLEAR SPAN OF 112 FEET
LENGTH OVER ALL 160 FEET
ROADWAY 26 FEET CLEAR
BUILT 1907

Unique in being one of the first concrete bridges designed strictly on the cantilever principle, making possible a shallow depth in the carrying girders

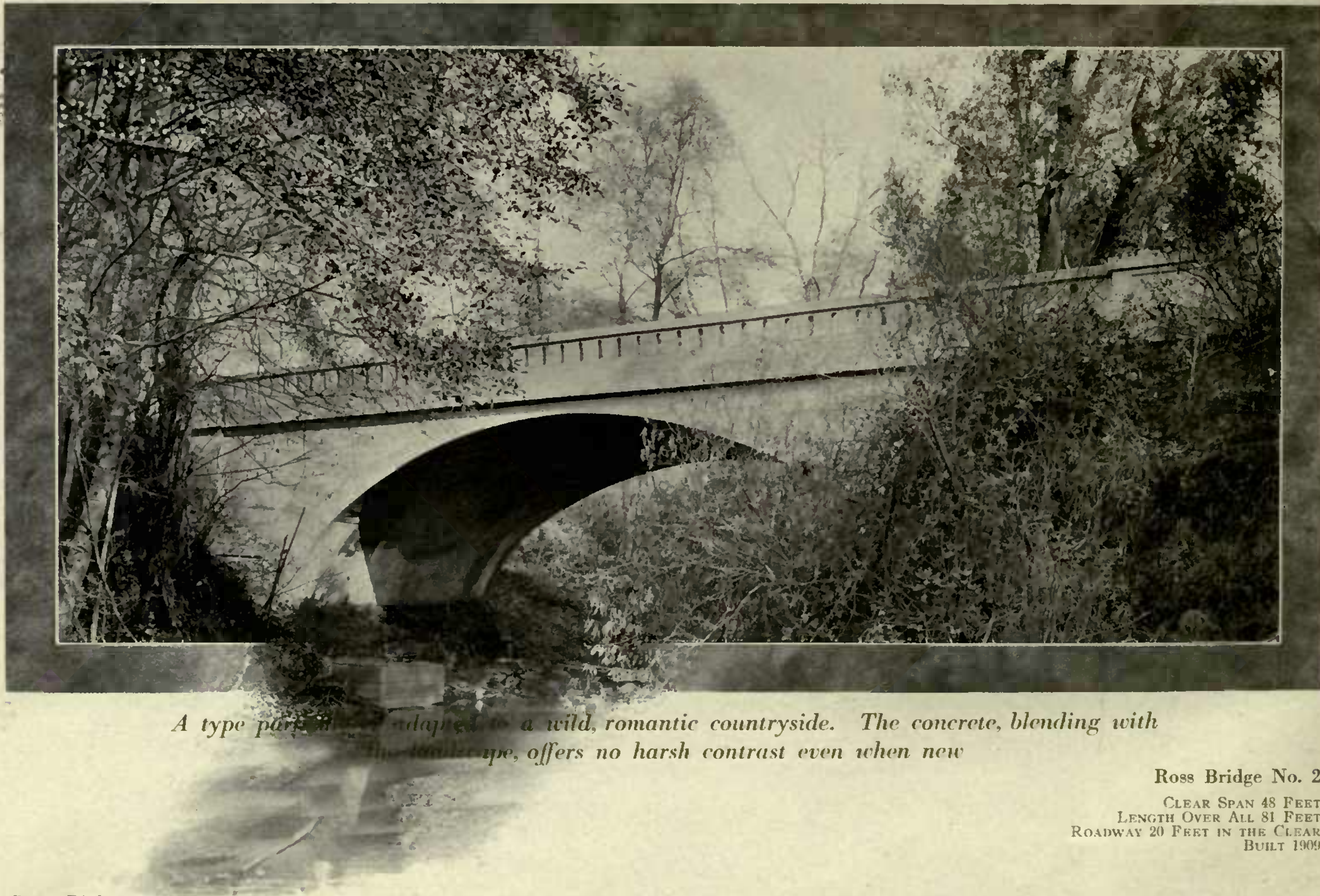
Ross Bridge No. 1
Ross Valley Station
Marin County, California

MAIN SPAN 45 FEET
END SPANS 20 FEET
LENGTH OVER ALL 87 FEET
ROADWAY 38 FEET
BUILT 1909

Of simple design and economical construction, it is readily seen that a bridge of this type can be made an ornament in similar locations

Ross Bridge No. 3

MAIN SPAN 22 FEET
END SPANS 10 FEET
LENGTH OVER ALL 43 FEET
ROADWAY 20 FEET IN THE CLEAR
BUILT 1909



A type particularly adapted to a wild, romantic countryside. The concrete, blending with the landscape, offers no harsh contrast even when new

Ross Bridge No. 2

CLEAR SPAN 48 FEET
LENGTH OVER ALL 81 FEET
ROADWAY 20 FEET IN THE CLEAR
BUILT 1909

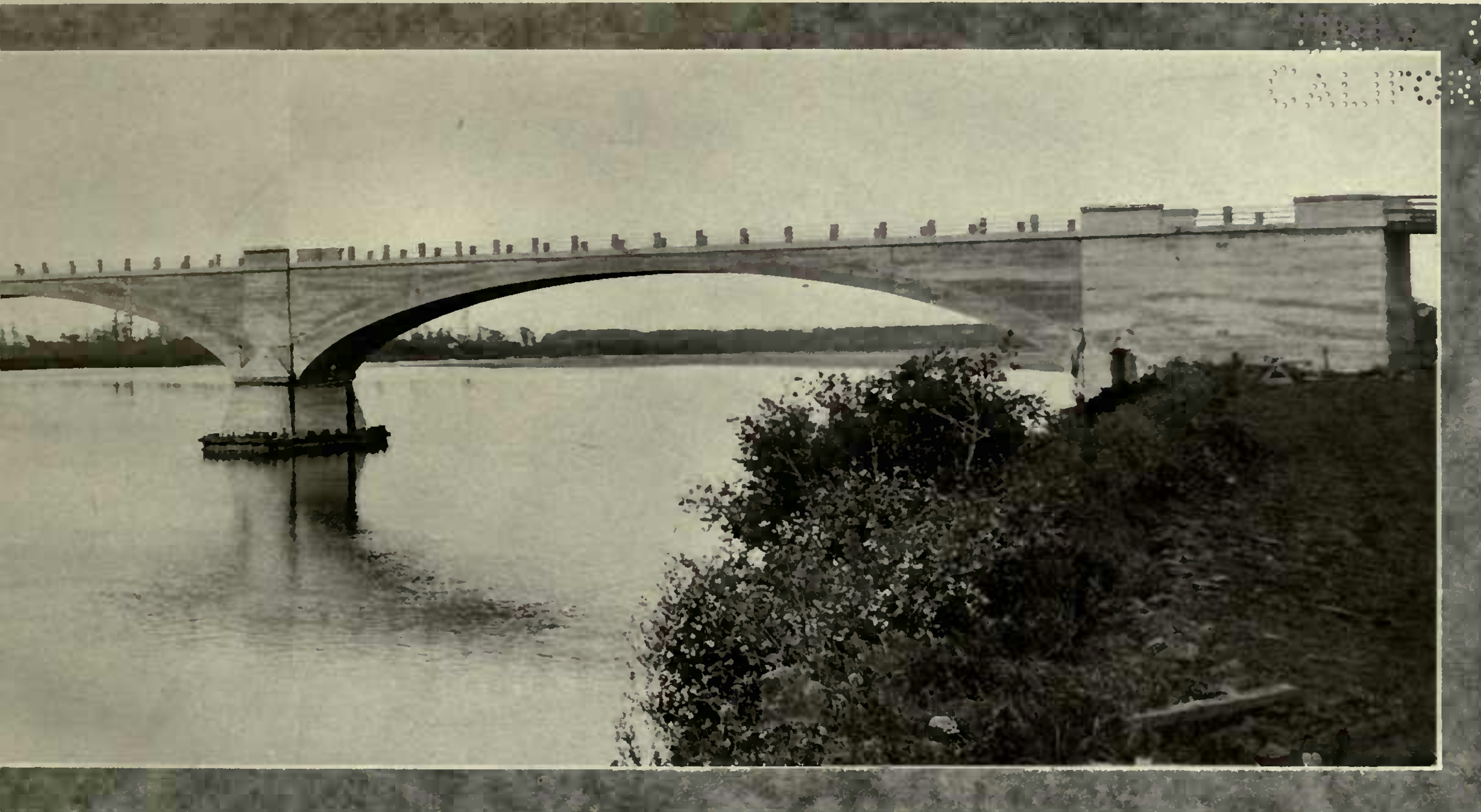
One of Marin County's artistic bridges; of the concrete girder type, simple and massive in design

Bridge at San Anselmo
Marin County, California

CLEAR SPAN 46 FEET
ROADWAY 40 FEET
LENGTH OVER ALL 80 FEET
BUILT 1910

One of the longest concrete bridges on the Pacific Coast. Each pier rests on 250 piles and is of extremely massi

Eel River Bridge
Near Eureka
Humboldt County, California



tion, to withstand the heavy drift. Eel River has a rapid current and is often filled with drifting saw logs

SEVEN 200 FOOT SPANS
LENGTH OVER ALL 1451 FEET
ROADWAY 22½ FEET CLEAR
BUILT 1911

Erected jointly by Fresno and Madera Counties, and built largely through the confidence created in favor of concrete construction by the erection of the Pollasky bridge

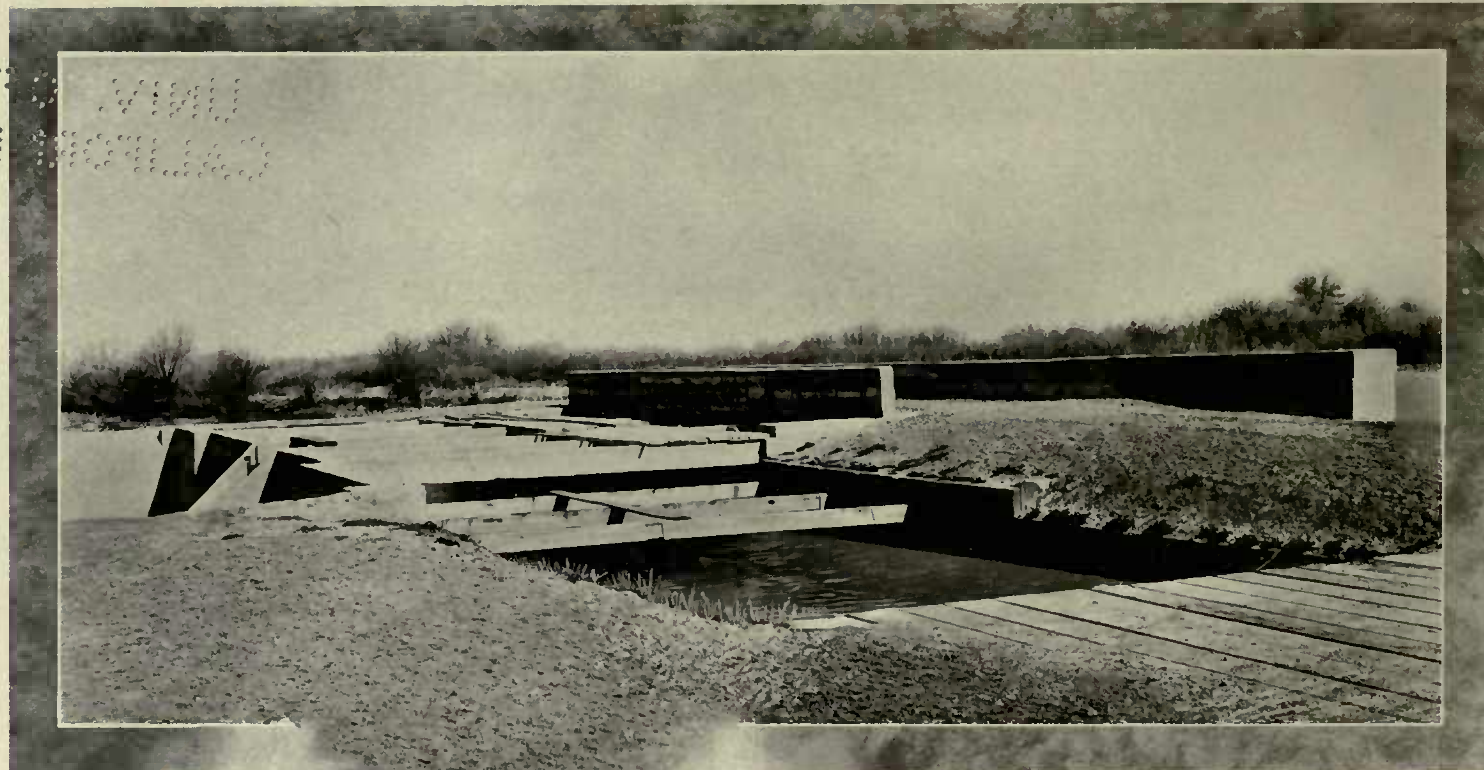
Skaggs Crossing Bridge
San Joaquin River
Between Fresno and Madera Counties, California

FIVE SPANS OF 80 FEET EACH
20 FOOT CLEAR ROADWAY
BUILT 1907

Erected jointly by Fresno and Madera Counties. The simplicity of design of this massive structure, one of the largest in California, led to ease of construction and consequent economy

Pollasky Bridge
Over San Joaquin River
Between Fresno and Madera Counties, California

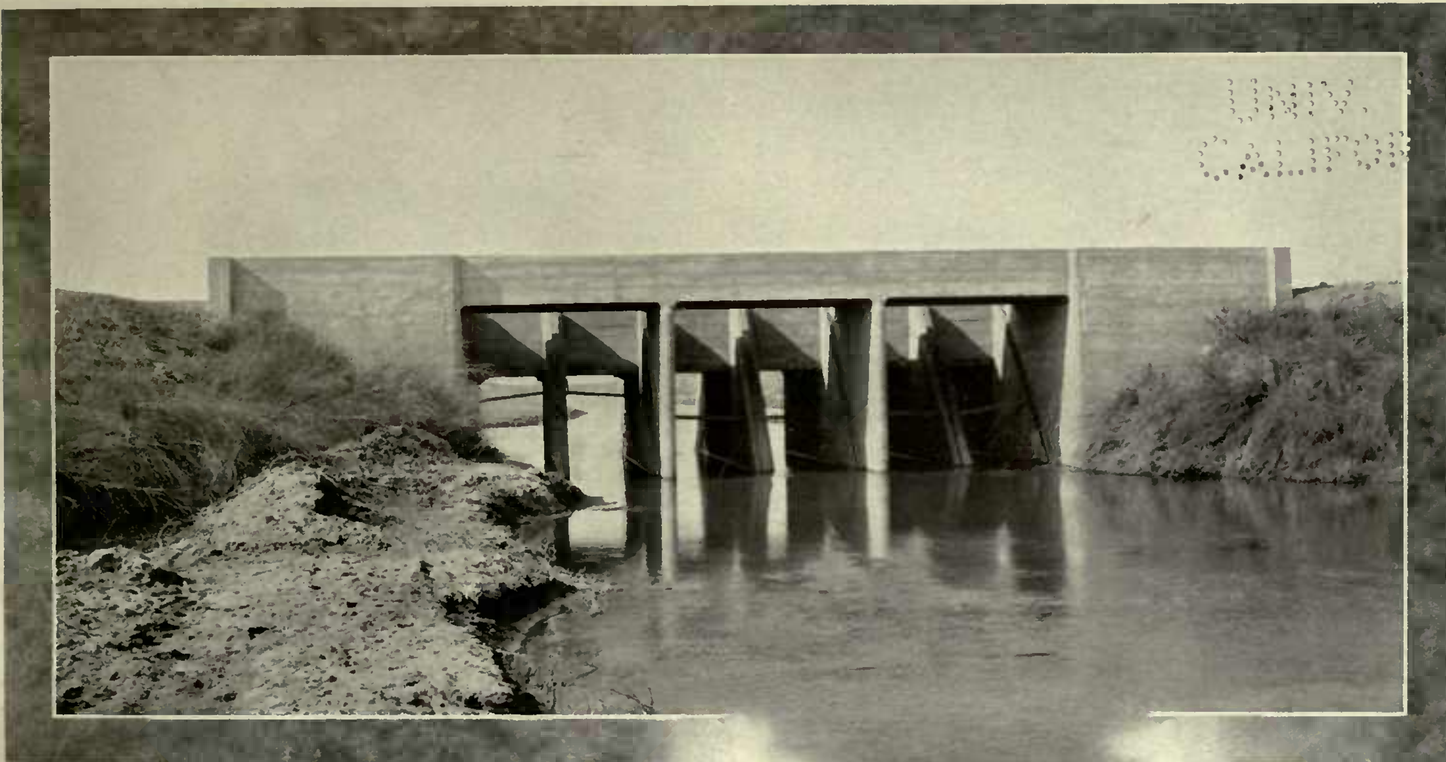
TEN 75 FOOT SPANS
LENGTH OVER ALL 780 FEET
ROADWAY 18 FEET CLEAR
BUILT 1905



A combination weir, flume and bridge, showing the roadway and flume. Note volume of water in the flume

Weir across Temple Slough at its junction with
San Joaquin River, Merced County, California
Built for Miller & Lux, Inc.

LENGTH OVER ALL 83 FEET, 6 INCHES
CARRYING ROADWAY 14 FEET WIDE
FLUME 4 BY 20 FEET
BUILT 1911



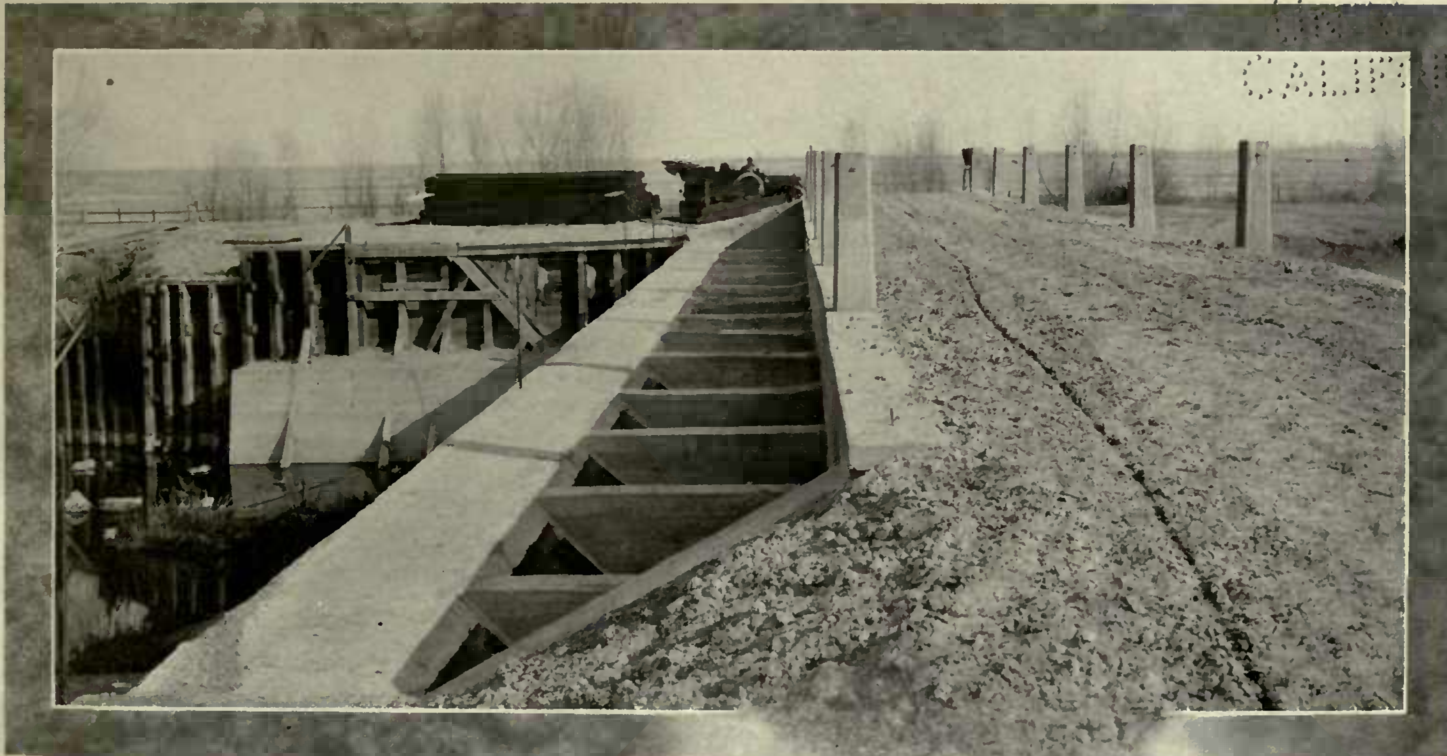
Another view of the Temple Slough weir. The roadway performs the double function of serving traffic and, through its weight, adding to the stability of the weir

Operated as easily as a timber structure. Not subject to deterioration, but increasing in strength with its age

This combination bridge and weir crosses the slough which controls the water from Buena Vista Lake

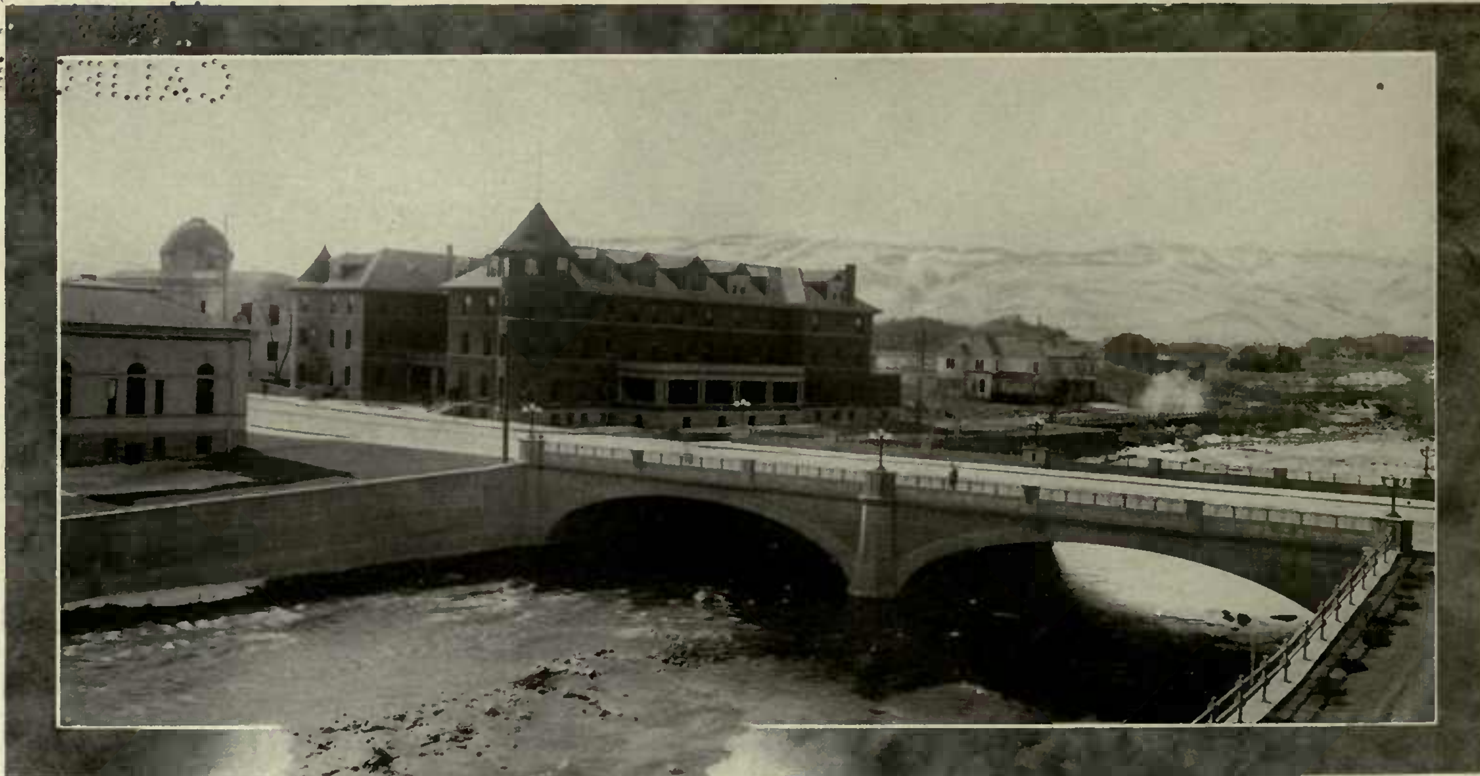
Old Headquarters Weir
Miller & Lux, Inc.
Kern County, California

Length Over All 163 Feet
Roadway 13 Feet in the Clear
Height from Floor of Weir to Bottom of Bridge Slab 19 Feet
Built 1911



Another view of the Old Headquarters Weir, showing the roadway and at the left a concrete slab that can be used for a footwalk

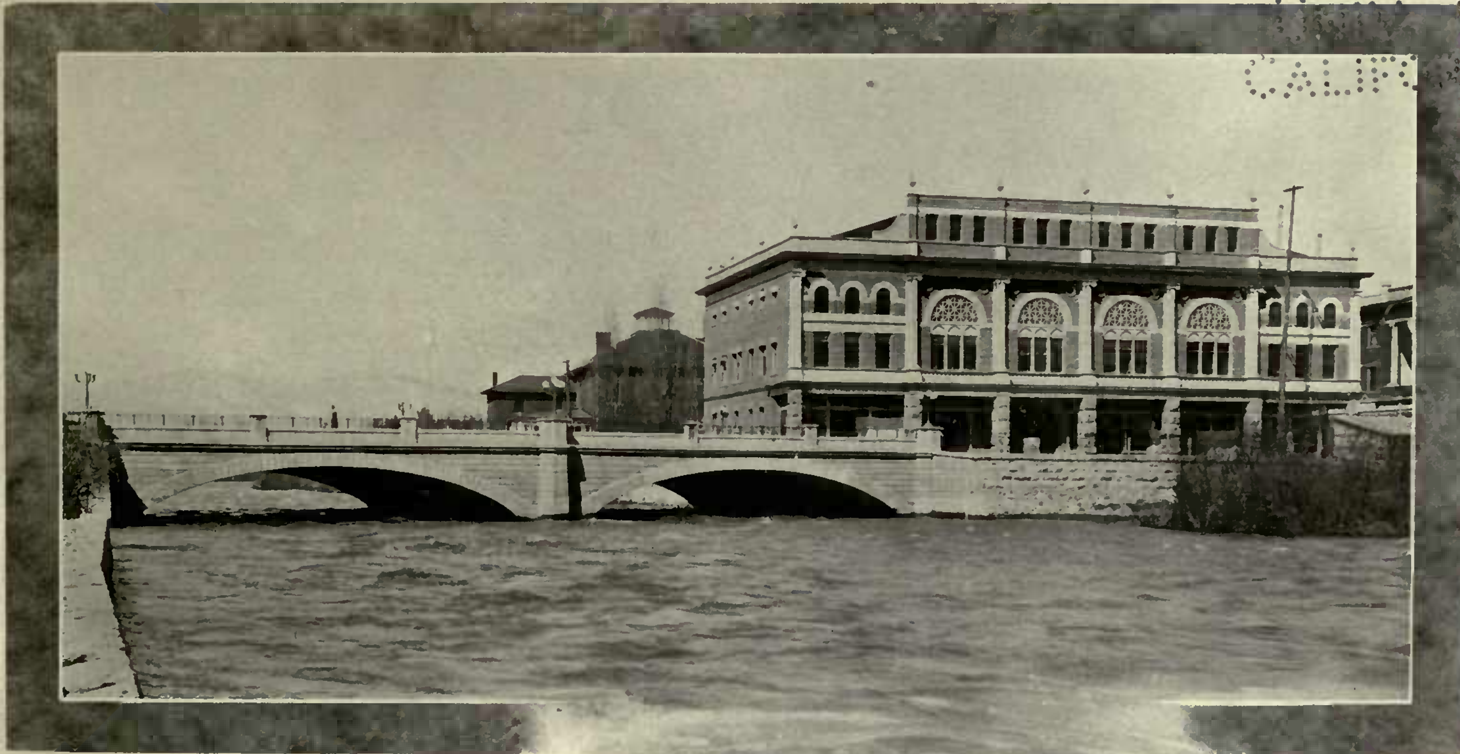
The maintenance expense and necessary renewals of the timber weir which was replaced by this substantial structure proved the economy of the latter



The construction here necessitated a full consideration of the rapid current of the river and its heavy drift of ice in winter—seen in the illustration

Virginia Street Bridge
Truckee River
Reno, Nevada

SHOWING THE UNUSUAL WIDTH OF ROADWAY, WHICH IS EQUAL TO THAT OF THE AVENUE ON WHICH IT IS LOCATED
ROADWAY AND SIDEWALKS 80 FEET



This is one of the first bridges built on the Pacific Coast of reinforced concrete—a pioneer. The only bridge shown, not in California

Profile view of Virginia Street Bridge, Reno, Nevada,
Showing it as it appears to the casual observer

TWO 65 FOOT SPANS
BUILT 1905

A 45 degree skew bridge, the railroad meeting each end on a 16 degree curve. Built on solid rock and carrying the heaviest locomotives hauling cars heavily laden with limestone

American River Bridge
Near Auburn
Placer County, California

THREE 140 FOOT CLEAR SPANS
LENGTH OVER ALL 652 FEET
BUILT 1911

This bridge stands 75 feet above the river, and the skew or angle at which the bridge crosses the river is here plainly seen. Note the heavy Mallet compound engine, indicating the unusual demand upon the structure

East approach of American River Bridge
Near Auburn,
Placer County, California
With birdseye view of river

The curve of this bridge is designed to afford ample passage for flood water, while conforming to the low street grade

Essex Street Bridge
San Luis Obispo

CLEAR SPAN 60 FEET
LENGTH OVER ALL 120 FEET
BUILT 1909

An example of the concrete girder bridge, where a considerable rise of water between low banks was provided for

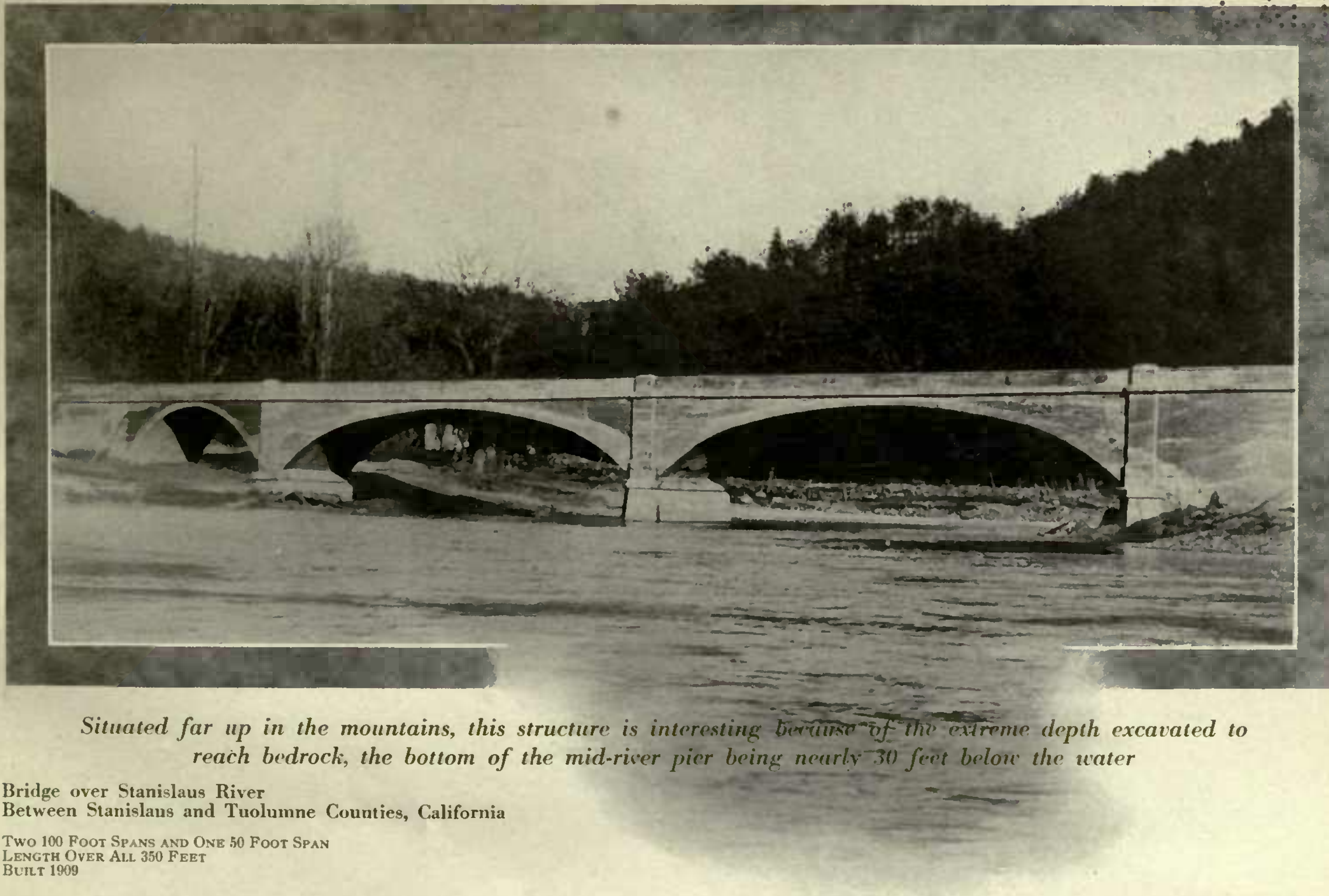
Marsh Street Bridge
City of San Luis Obispo
San Luis Obispo County, California

Clear Span of 40 Feet
Length Over All 80 Feet
Built 1909

Built to replace an old type combination structure of steel and wood. Notable for extremely low cost of construction

Lindo Channel Bridge
Chico
Butte County, California

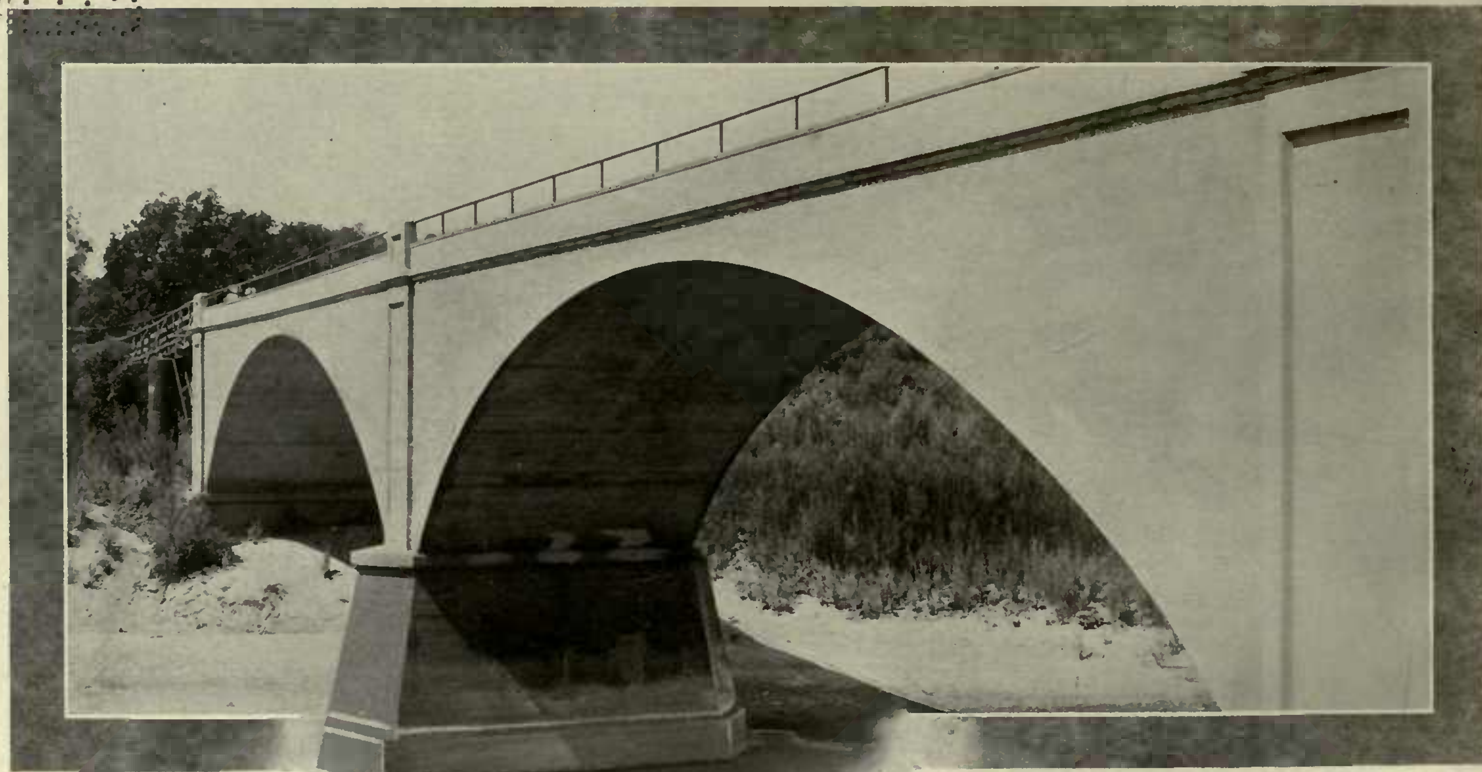
Two Spans, Each 87 Feet Clear
Roadway 28½ Feet Clear
Length Over All 204 Feet
Built 1912



Situated far up in the mountains, this structure is interesting because of the extreme depth excavated to reach bedrock, the bottom of the mid-river pier being nearly 30 feet below the water

Bridge over Stanislaus River
Between Stanislaus and Tuolumne Counties, California

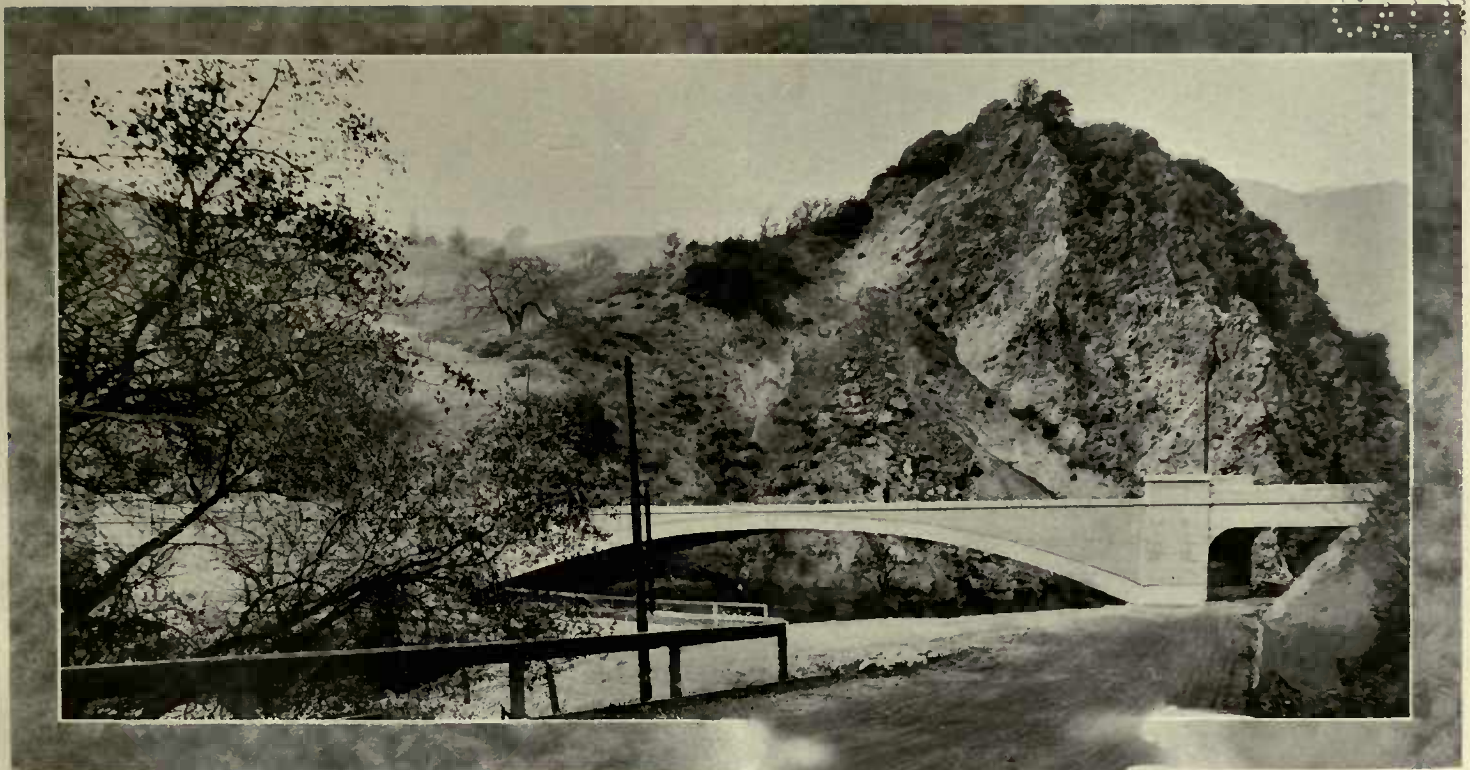
TWO 100 FOOT SPANS AND ONE 50 FOOT SPAN
LENGTH OVER ALL 350 FEET
BUILT 1909



This substantial highway bridge spans the Stanislaus River near Modesto, connecting San Joaquin and Stanislaus Counties

Ripon Bridge

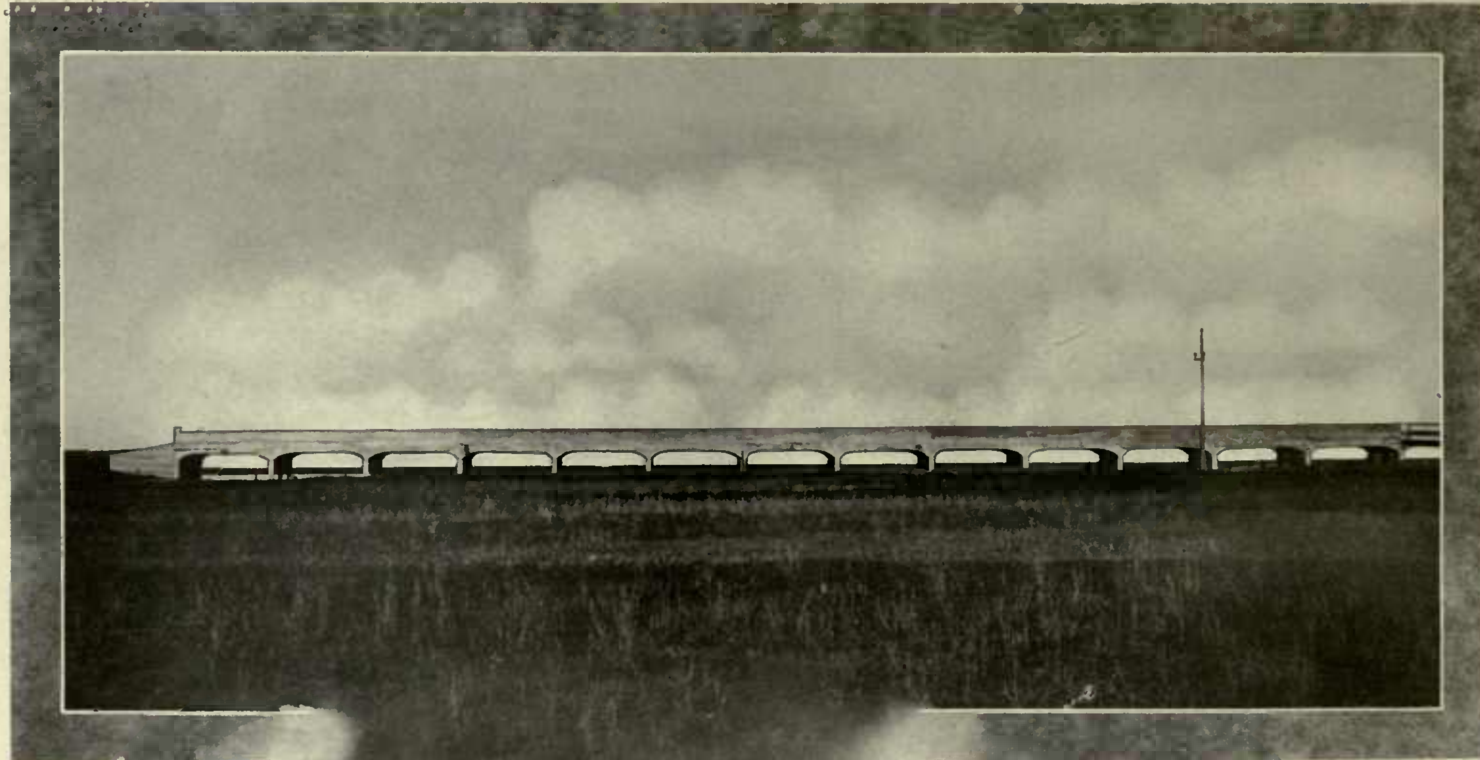
Two 110 Foot Spans
Length Over All 280 Feet
Built 1908



This is an original design accepted by the Landscape Engineers of Alum Rock Park, who decided that its lines were in complete accord with its surroundings. It was constructed by the Peninsular Railway Company to carry their heavy interurban cars

Alum Rock Bridge
San Jose, California

CLEAR SPAN 130 FEET
APPROACH SPANS 40 FEET
LENGTH OVER ALL 250 FEET
BUILT 1913



This bridge has been built in sections of five spans at a time, and when completed will be 1100 feet long. Designed as a series of continuous flat spans, and remarkable for its low cost

Trestle Bridge
Maxwell and Colusa Road
Colusa County, California

All Spans 20 Feet
Total Length on Completion 1100 Feet

STRAIN SHEET

The stress diagram, erroneously but universally called strain diagram, should be made for all arches, else the stresses in the materials are not definitely known. The Elastic Theory for fixed end arches is recognized by most engineers as being the best analysis for structures of this type. Stresses should be obtained for dead and live loads, rise or fall of temperature, and shortening of the arch from superimposed loads. In providing concrete and reinforcing steel to meet these conditions, that combination of loading which produces maximum stresses in the arch is used.

Choice of the shape of the arch is a matter of vital importance from the standpoint of economy, although this fact is not generally recognized. A slight change in the shape produces material changes in the stresses. The matter is complicated by the fact that no known law exists by which the proper curve may be determined without a cut and try. The engineer must rely solely upon his experience in his first choice of curve. This fact was well demonstrated in the case of the Eel River Bridge, a cut of which is shown on pages 20-21.

The designers made three different curves of the same span and same rise before obtaining the one which they considered correct. For each individual arch with a given rise and span, there exists a curve that produces minimum stresses, and it is the function of the designer to obtain this curve.

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