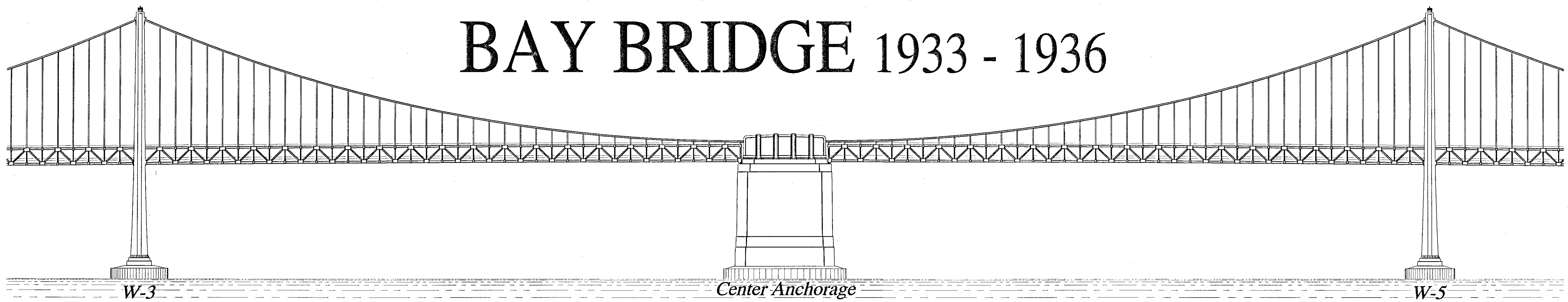
SAN FRANCISCO OAKLAND BAY BRIDGE 1933 - 1936



W-3

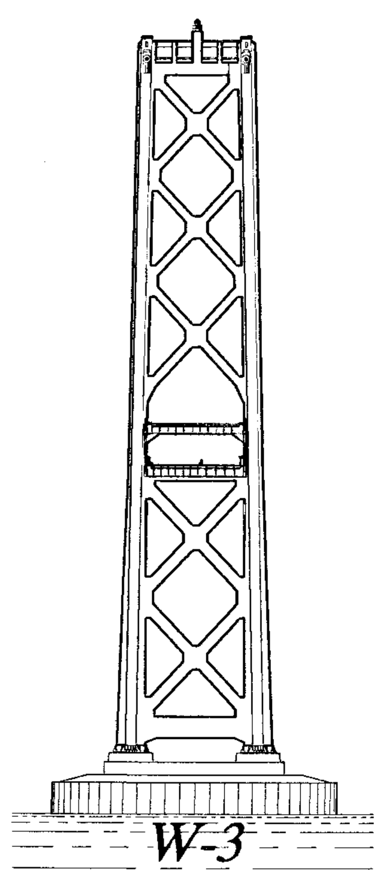
Center Anchorage

W-4

W-5

Suspension Span

SCALE IN FEET 0 10 20 30
SCALE IN METERS 0 3 6 9



W-3

Suspension Tower

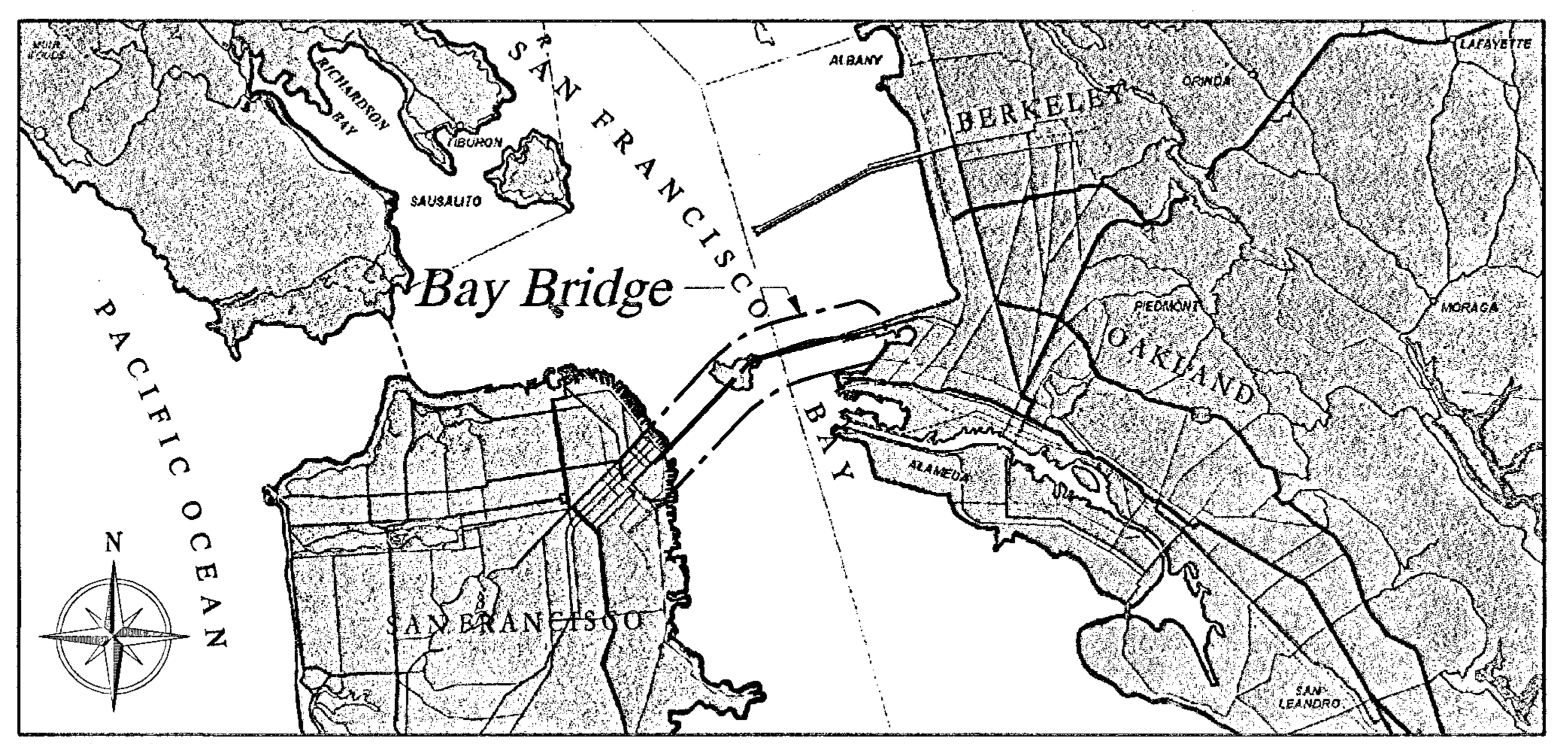
THE CALIFORNIA TOLL BRIDGE AUTHORITY ACT OF 1929 LED TO THE CREATION OF THE TOLL BRIDGE AUTHORITY, AUTHORIZED TO "LAY OUT, ACQUIRE, AND CONSTRUCT A HIGHWAY CROSSING FROM THE CITY OF SAN FRANCISCO TO THE COUNTY OF ALAMEDA". THE PROJECT WAS FUNDED ON OCTOBER 10, 1932 BY THE SALE OF BONDS AND GROUND BREAKING OCCURRED ON JULY 9, 1933. THE SAN FRANCISCO OAKLAND BAY BRIDGE WAS OPENED TO VEHICULAR TRAFFIC ON NOVEMBER 12, 1936.

THE SAN FRANCISCO OAKLAND BAY BRIDGE IS ONE OF THE WORLD'S MOST COMPLEX BRIDGES. IT CONSISTS OF A SERIES OF CONNECTING STRUCTURES CARRYING TWO LEVELS OF TRAFFIC FROM SAN FRANCISCO TO OAKLAND, CROSSING YERBA BUENA ISLAND. THE UPPER DECK ORIGINALLY CARRIED SIX LANES OF TWO WAY TRAFFIC FOR AUTOMOBILES. THE LOWER DECK CONTAINED THREE LANES FOR BUS AND TRUCK TRAFFIC AND TWO TRACKS FOR AN ELECTRIC RAILROAD SYSTEM. THE BRIDGE IS COMPRISED OF MANY STRUCTURAL SYSTEMS, INCLUDING CONCRETE VIADUCTS, STEEL SUSPENSION SYSTEMS, STEEL CANTILEVER TRUSSES, THROUGH TRUSSES, DECK TRUSSES AND GIRDER SYSTEMS. THE DOUBLE SUSPENSION SPAN, WITH ITS CENTER ANCHORAGE, IS ONE OF THE BRIDGE'S UNIQUE FEATURES. THE TUNNEL THROUGH YERBA BUENA ISLAND IS STILL ONE OF THE LARGEST DIAMETER VEHICULAR TUNNEL BORES IN THE WORLD. THE TOTAL LENGTH OF THE BRIDGE STRUCTURES, NOT INCLUDING THE ON-GRADE PORTION FROM THE TOLL PLAZA TO THE BEGINNING OF THE BRIDGE/VIADUCT STRUCTURES, IS 26,286.95 FEET (5 MILES) WHICH EXTENDS FROM THE EAST BAY SHORELINE TO THE ORIGINAL 5TH STREET ACCESS.

THE SAN FRANCISCO OAKLAND BAY BRIDGE IS CONSIDERED ONE OF AMERICA'S MOST IMPORTANT BRIDGES. IT WAS THE LARGEST BRIDGE IN THE WORLD WHEN IT WAS BUILT. IN 1952, THE AMERICAN SOCIETY OF CIVIL ENGINEERS SELECTED THE BRIDGE AS ONE OF THE "SEVEN ENGINEERING WONDERS OF THE UNITED STATES" AS PART OF THEIR CENTENNIAL YEAR CELEBRATION.

THIS RECORDING PROJECT HAS BEEN DONE AS PART OF AN EXTENSIVE SEISMIC UPGRADE OF THE BRIDGE BEING EXECUTED BY THE CALIFORNIA DEPARTMENT OF TRANSPORTATION. THE DOCUMENTATION WAS DONE IN ACCORDANCE WITH THE HISTORIC AMERICAN ENGINEERING RECORD (HAER) STANDARDS.

Index to Drawings



Vicinity Map (NOT TO SCALE)

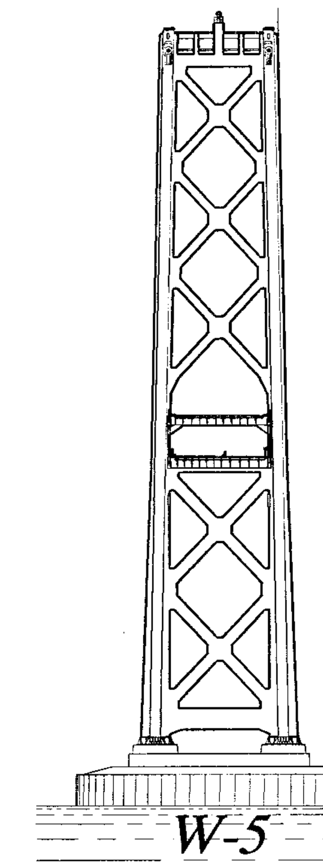
SOURCE: SIXTH ANNUAL REPORT SAN FRANCISCO OAKLAND BAY BRIDGE, 1939

UTM COORDINATES: SAN FRANCISCO APPROACH: 10/0552872/4181230
EAST BAY APPROACH: 10/0559248/4186043

THE HAER PROGRAM, ADMINISTERED BY THE HISTORIC AMERICAN BUILDINGS SURVEY/HISTORIC AMERICAN ENGINEERING RECORD DIVISION (HABS/HAER) OF THE NATIONAL PARK SERVICE, U.S. DEPARTMENT OF THE INTERIOR, IS PART OF A LONG-RANGE PROGRAM TO DOCUMENT THE ENGINEERING, INDUSTRIAL, AND TRANSPORTATION HERITAGE OF THE UNITED STATES.

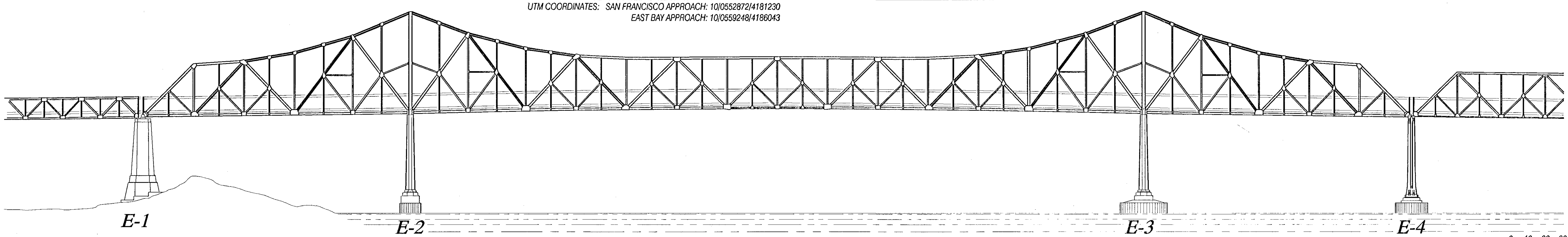
THE FIELD WORK, MEASURED DRAWINGS, HISTORICAL REPORTS, AND PHOTOGRAPHS WERE PREPARED UNDER THE DIRECTION OF JOHN NELSON, AIA OF HANSEN, MURAKAMI, ESHIMA, ARCHITECTS AND PLANNERS. DAN PETERSON, AIA, HISTORIC ARCHITECT OF DAN PETERSON, AIA AND ASSOCIATES, INC. SERVED AS THE HABS/HAER CONSULTANT AND DEVELOPED THE LAYOUT OF THE HAER DRAWINGS WHICH WERE PREPARED BY HANSEN, MURAKAMI, ESHIMA ARCHITECTS AND PLANNERS UNDER THE DIRECTION OF ZACHARY GOODMAN, ARCHITECT. THE HISTORICAL NARRATIVE WAS PREPARED BY STEPHEN D. MIKESELL OF JRP HISTORICAL CONSULTING SERVICES. THE PHOTOGRAPHY WORK WAS DONE BY FRANK DERAS OF FRANK DERAS PHOTOGRAPHY AND DENNIS HILL OF DENNIS HILL PHOTOGRAPHY. MARK KETCHUM, PH.D., P.E. OF OPAC CONSULTING ENGINEERS PROVIDED THE ENGINEERING EXPERTISE FOR THE PROJECT.

THE ORIGINAL CONSTRUCTION OF THE SAN FRANCISCO OAKLAND BAY BRIDGE WAS DIVIDED INTO A SERIES OF CONTRACTS. THE APPROACH OF THE HAER DRAWINGS HAS BEEN TO RESPECT THOSE DIVISIONS AND PROVIDE A SERIES OF INTERPRETIVE DRAWINGS ILLUSTRATING THE CONSTRUCTION AND THE COMPONENTS OF ALL SYSTEMS. THE INFORMATION USED TO DEVELOP THIS SERIES OF DRAWINGS WAS OBTAINED FROM THOUSANDS OF DRAWINGS, PHOTOGRAPHS, REPORTS AND ENGINEERS' NOTES AND DESCRIPTIONS. THE CALIFORNIA DEPARTMENT OF TRANSPORTATION HAS RETAINED ALL OF THE ORIGINAL CONSTRUCTION DRAWINGS, SHOP DRAWINGS, CONSTRUCTION PHOTOGRAPHS AND A FINAL REPORT WHICH CONTAINS OVER 100 AS-BUILT DRAWINGS. THE TERMINOLOGY AND PIER NUMBERING ARE THOSE THAT WERE USED ON THE ORIGINAL CONSTRUCTION DRAWINGS. THE PIERS ARE NUMBERED FROM WEST TO EAST AND ALL OF THE ELEVATIONS ARE VIEWED FROM THE SOUTH.



W-5

Suspension Tower



E-1

E-2

E-3

E-4

Cantilever Span

SCALE IN FEET 0 10 20 30
SCALE IN METERS 0 3 6 9

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT, 1999
TEXT BY: DAN PETERSON, AIA

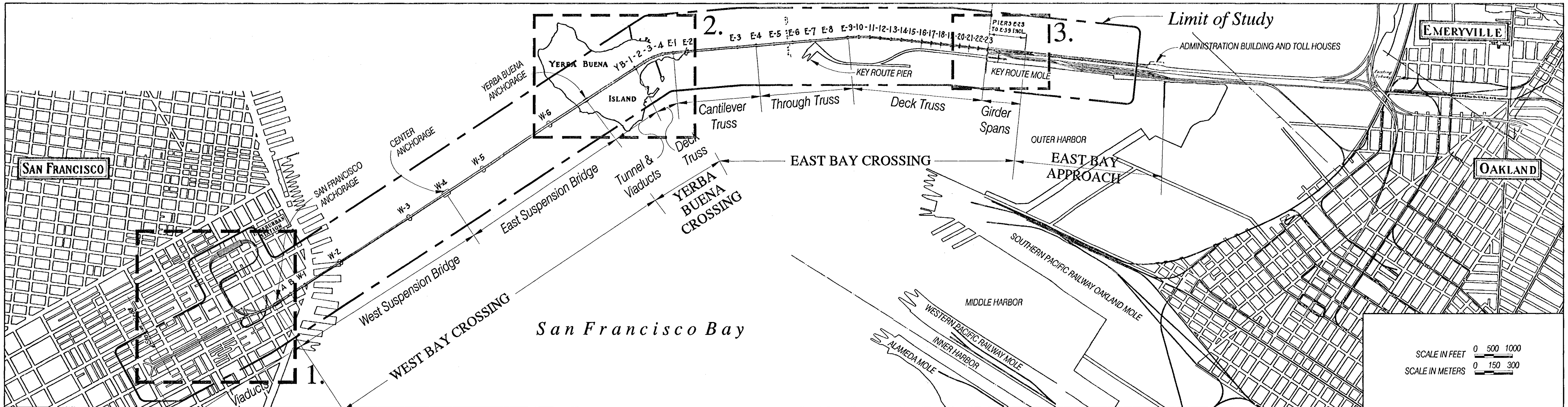
SAN FRANCISCO OAKLAND BAY BRIDGE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

SAN FRANCISCO OAKLAND BAY BRIDGE (OAKLAND–SAN FRANCISCO BAY BRIDGE)
SPANNING THE SAN FRANCISCO BAY — SAN FRANCISCO CITY AND COUNTY — CALIFORNIA

SHEET 1 OF 20

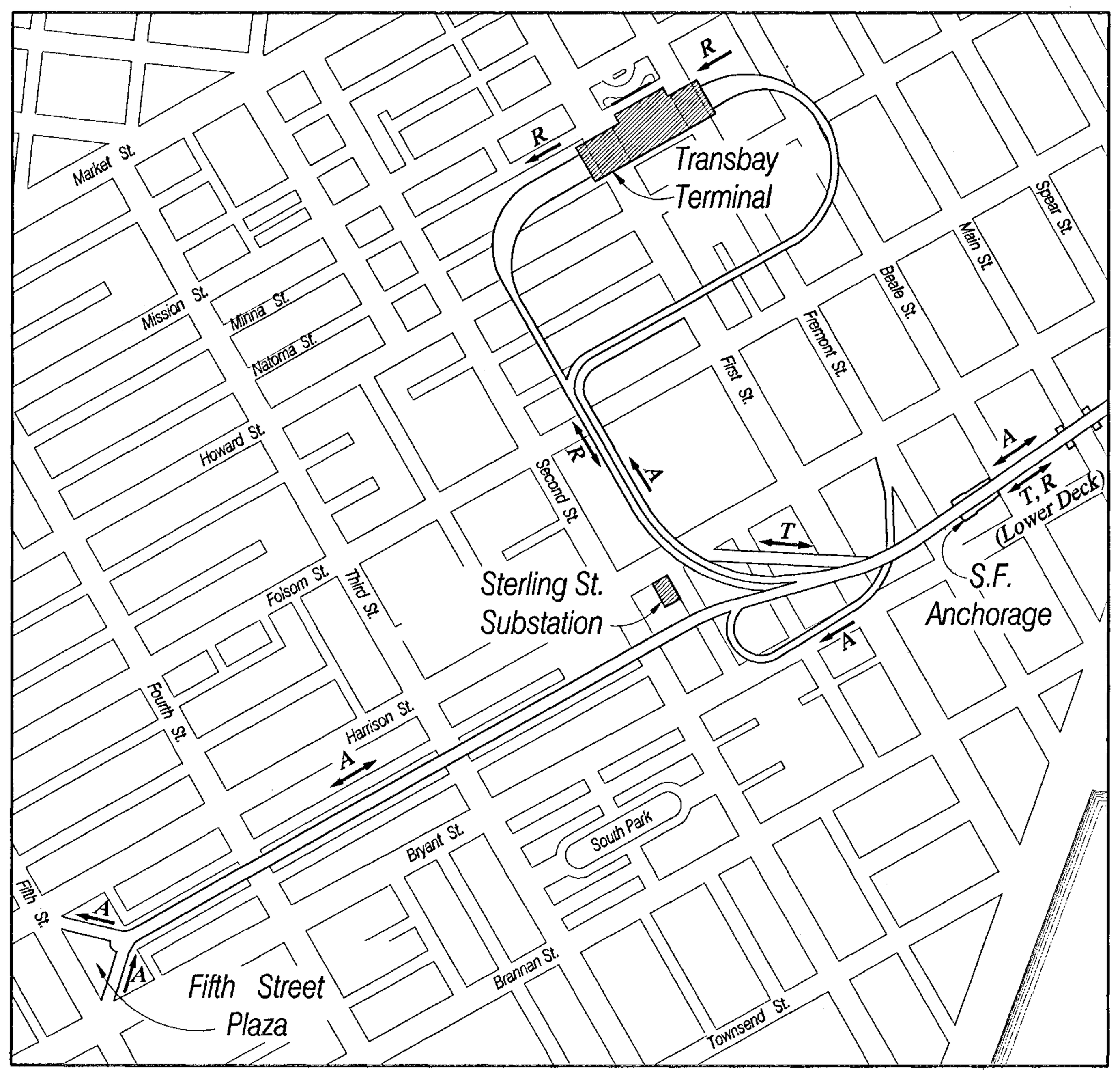
HISTORIC AMERICAN ENGINEERING RECORD CA-32

TRIM LINE

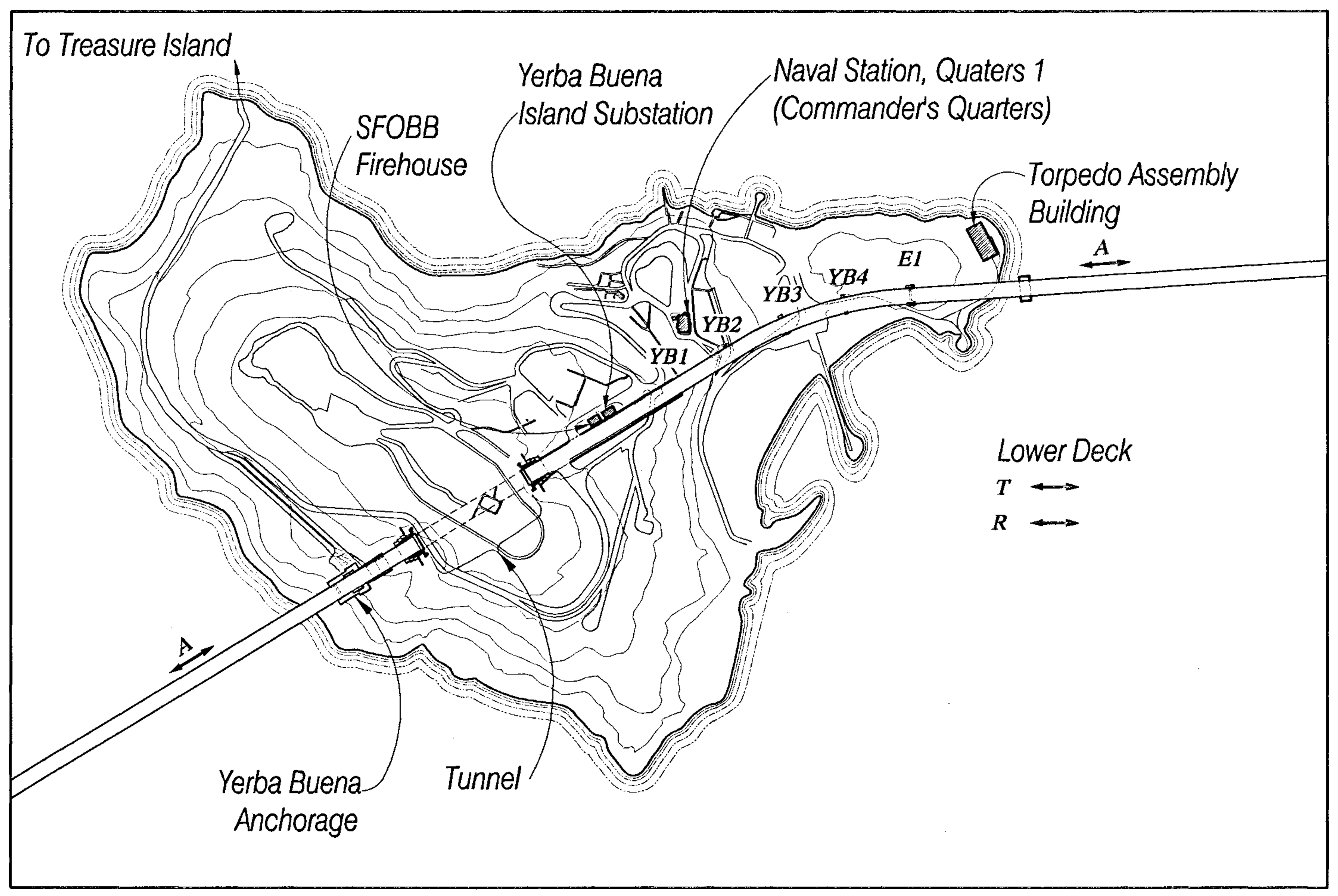


SOURCE: FIRST ANNUAL REPORT SAN FRANCISCO OAKLAND BAY BRIDGE, 1934

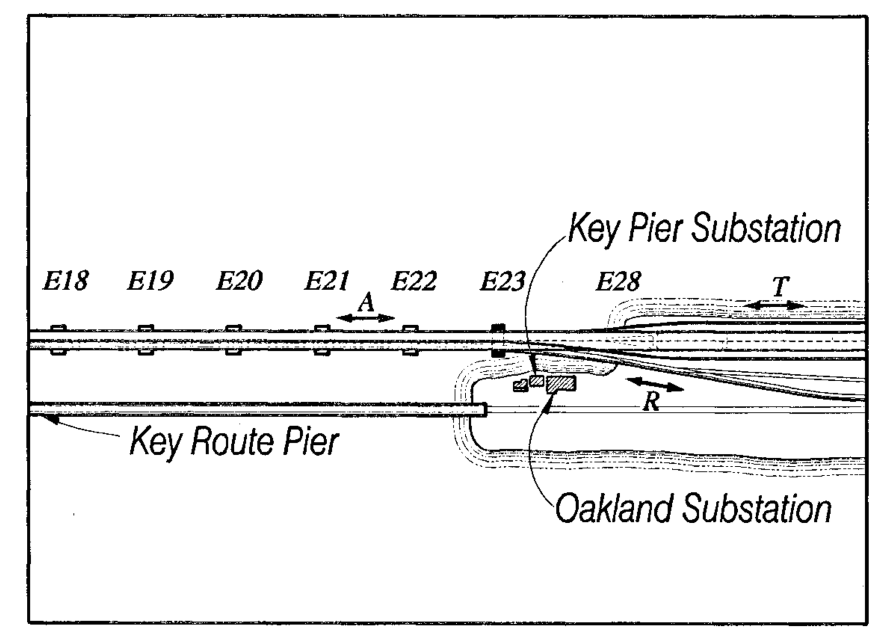
General Plan



1. San Francisco Approach



2. Yerba Buena Island



3. East Bay Approach

Symbol Key

AUTOMOBILE TRAFFIC	A
TRUCK TRAFFIC	T
RAILWAY TRAFFIC	R
DIRECTION OF TRAFFIC	←

N

SCALE IN FEET 0 250 500
SCALE IN METERS 0 50 100 150

KEY PLANS

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT, 1999
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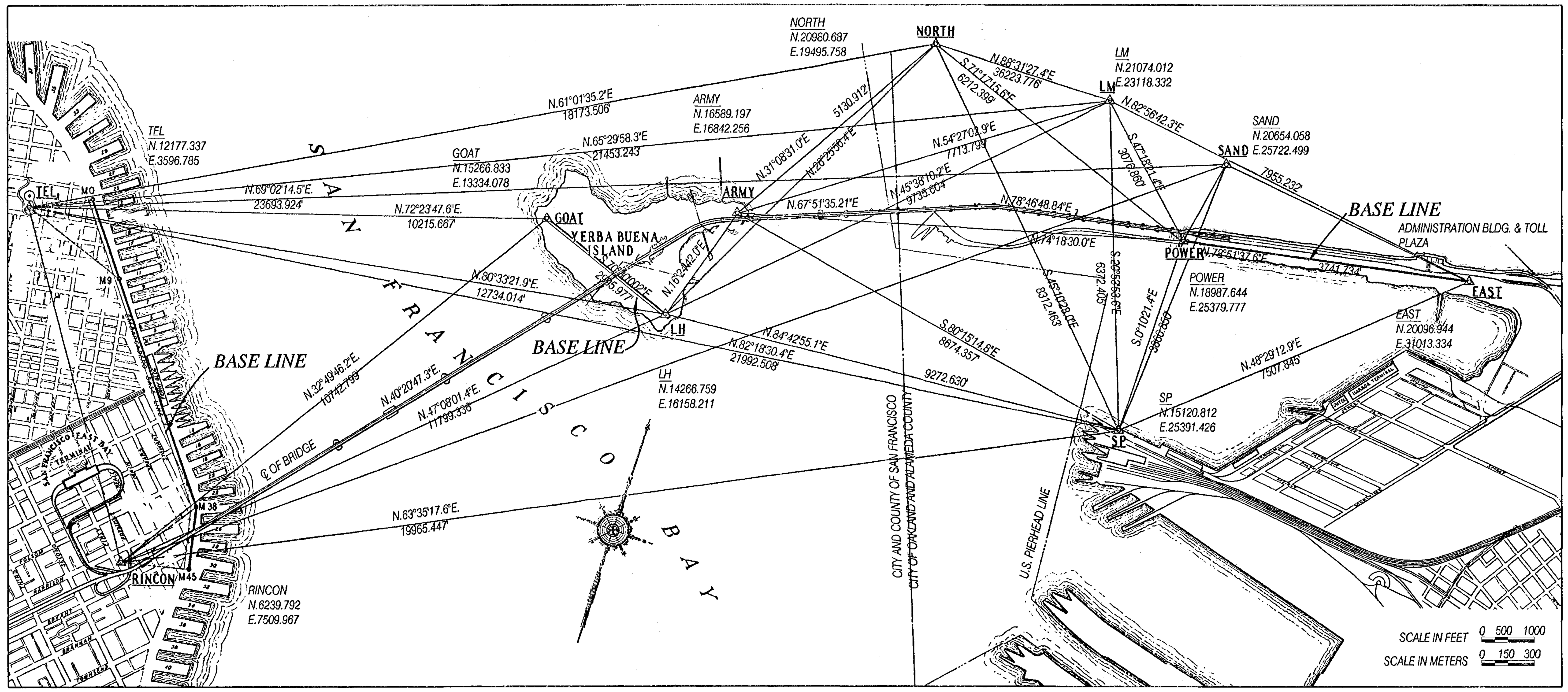
TRIM LINE

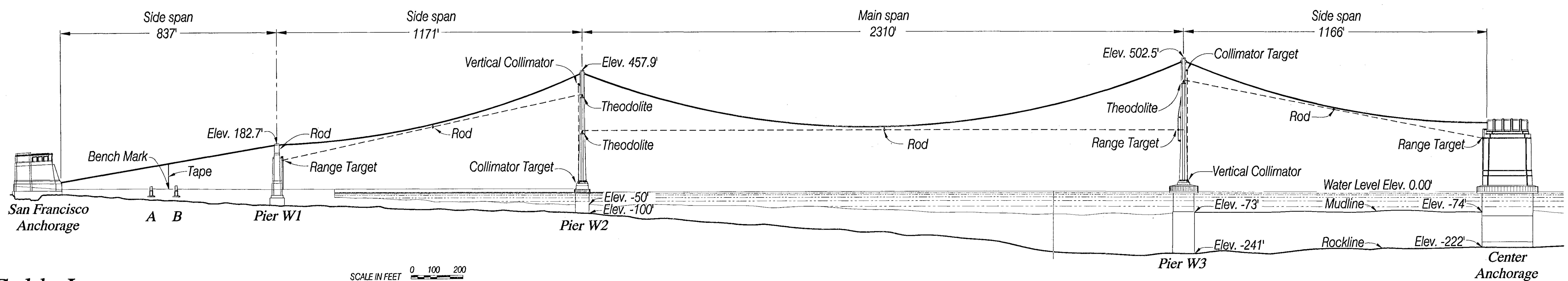
TRIM LINE

Triangulation Net

Surveys required during construction called for a variety of methods. Because of the magnitude and complexity of the surveys required, and the necessity for speed and accuracy, a Department of Triangulation and Surveys was formed to establish the necessary survey data needed to locate the structures for the San Francisco-Oakland Bay Bridge. A triangulation net consisting of 11 stations was developed; two were on the west shore, three were on Yerba Buena Island, three were deep water locations and three were on the east shore. Base lines were established to control the accuracy of locating points by triangulation. Three base lines were set up: one along the San Francisco waterfront, one on the west side of Yerba Buena Island, and one along the Key Route Mole in Oakland. A fifty meter Invar tape was used to establish the dimensions along the base line. Three of these tapes were used for all surveying and were calibrated at the Bureau of Standards laboratories in Washington D.C.. Each of the triangulation stations contained a theodolite, and short wave radios to communicate to all construction stations and boats. The observer's platform and instruments were protected from the warping effect of the sun's rays and the vibrations from the wind by shelter houses. The angles of the triangulation net were measured at night when the atmosphere was more uniform, contained less smoke, and heat waves were less noticeable. It was also possible to obtain greater accuracy by defining points with artificial light. The accuracy of the bridge net was 1 foot in 76,500 feet (14.5 mi.). This meant that the differential between the triangulation net and chained dimensions was 0.037 feet in a distance of 6,173 feet. Range poles (lining rods) were placed on the top of each triangulation station and were used on daylight locations to establish mooring anchors, construction docks, submarine cables and caissons. The range poles were 7 inches in diameter and were the largest ever used. A common datum point was established on Telegraph Hill in San Francisco so that all of the bridge sections would ultimately align. The common datum point was transferred to the Oakland side in two steps , from Telegraph Hill to the triangulation station on Yerba Buena Island (9,660 feet) and then to the Albers Mill building, adjacent to the Southern Pacific Mole in Oakland (10,290 feet). Datum points were then transferred to various points of the construction using a transbay level system established by United States Coast and Geodetic Survey.



SOURCE: SIXTH ANNUAL REPORT SAN FRANCISCO OAKLAND BAY BRIDGE, 1939.



Cable Layout

The layout of the cable curve (catenary) required fourteen separate control systems. Graphs and tables were prepared so that the cable could be adjusted to the correct position by setting the mid-span point at the proper elevation for any reasonable condition of temperature, span length, and change in elevation of the supports. A five hundred foot model was constructed to evaluate these factors. The rate and extent of tower deflections, (up to 1 foot) due to a 40 degree temperature differential, was determined by observing the locations of the tower tops by a vertical collimator throughout a twenty-four hour period. The vertical collimators were also used during the cable spinning to monitor the vertical alignment of the towers. Observation platforms, roofed and enclosed by canvas, were erected at desired elevations on the tower and contained equipment similar to that in the triangulation net stations. The mid-span rods and range targets were illuminated for night work, and the theodolites were equipped for electrical illumination of the cross hairs. All observations were taken at night because the temperature of the wires could be more accurately measured and the rate of movement of the towers and rockers was at a minimum. Guide wire temperatures were obtained from thermometers encased in short lengths of cable wire, and strand temperatures were obtained by inserting metal encased thermometers between the wires.

SURVEY DATA

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT, 1999 TEXT BY: DAN PETERSON, AIA

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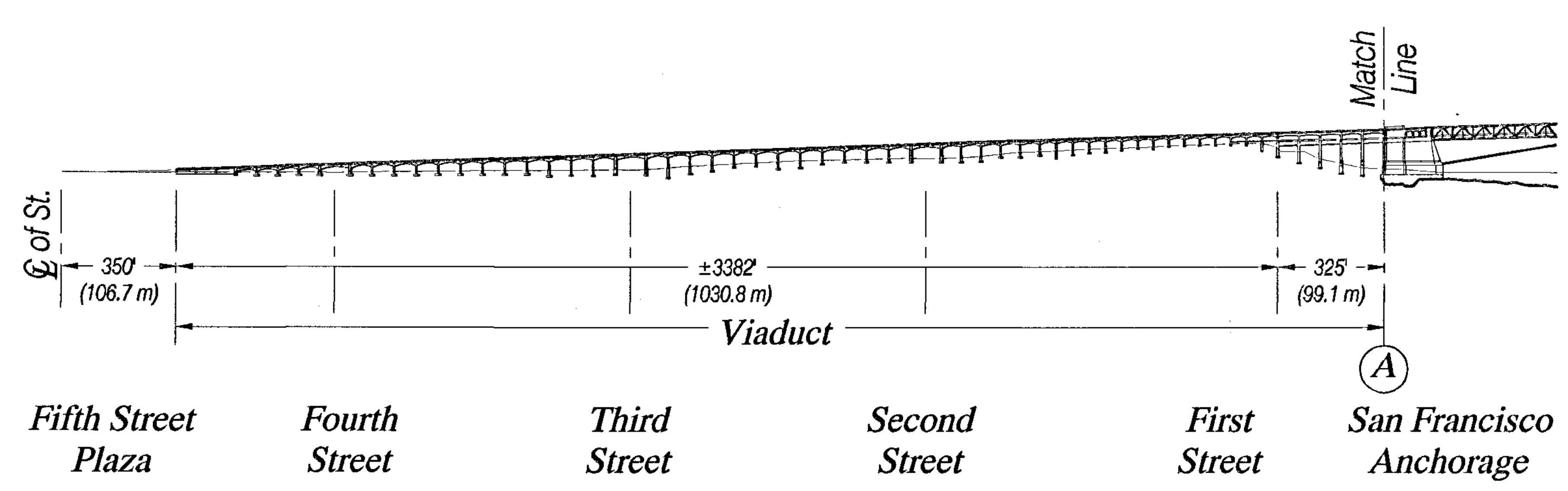
TRIM LINE

San Francisco Approach

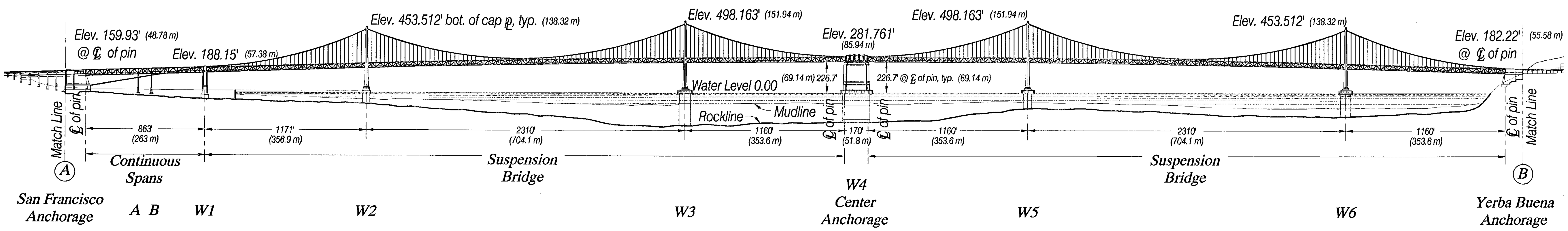
The original San Francisco approach for automobiles was a long concrete viaduct structure that began at Fifth Street (between Harrison and Bryant) and extended to the San Francisco anchorage. There were intermediate separate entrance and exit ramps just west of the anchorage that are not shown in these elevations. Most of the viaduct had a single level deck for automobiles. However, just west of the anchorage, the viaduct had two levels of decks. The lower deck was for truck and train traffic, which entered and exited the bridge near First street. The anchorage was located inland in order to be constructed on unfilled material and serve as a gravity anchorage.



San Francisco Approach

West Bay Crossing

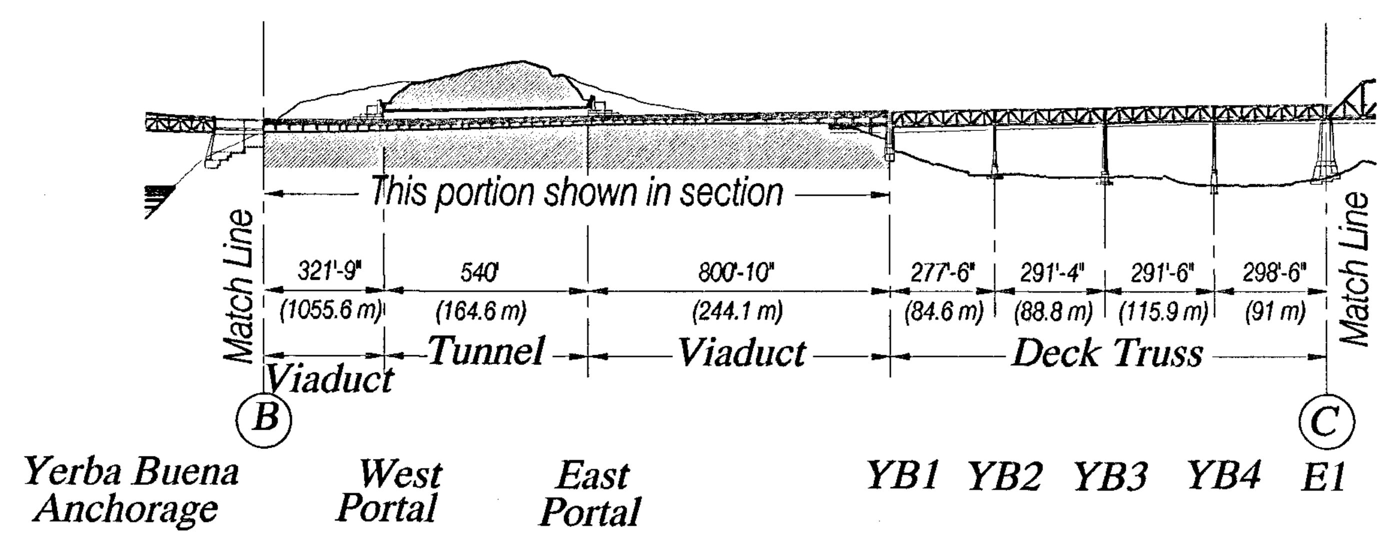
The West Bay Crossing consists of tandem 2,310 foot span suspension bridges connected by a massive center anchorage. The side spans are 1,160 feet long except at the west end of the western span which is 1,171 feet. The bridge originally contained an upper deck for automobiles and a lower deck for trucks and trains. A continuous steel deck truss spans between the San Francisco anchorage and pier W-1.



West Bay Crossing

Yerba Buena Crossing

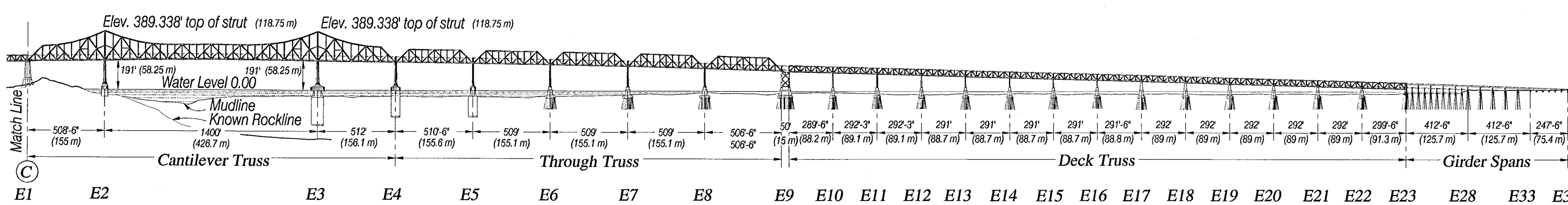
The Yerba Buena Crossing consists of a main tunnel with concrete portals, and viaducts linking both levels of traffic on the West Bay and East Bay Crossings. The tunnel is a tiled concrete vault supported by concrete sidewalls. A curved steel deck truss viaduct extends over the east side of the island to pier E-1, which marks the beginning of the East Bay Crossing.



Yerba Buena Crossing

East Bay Crossing

The East Bay Crossing consists of a cantilever truss, five through trusses, fourteen deck trusses, and a series of girder spans at the Oakland approach. Due to the extreme depths of mud on the bay floor, none of the foundations between Yerba Buena Island and the Oakland Mole bear on bedrock. Instead, they are supported on a layer of silty clay and sand several hundred feet below the bottom of the bay.



East Bay Crossing

ELEVATIONS

(South Elevations Illustrated)

SCALE IN FEET 0 200 400
SCALE IN METERS 0 40 80 120

HISTORIC AMERICAN ENGINEERING RECORD CA-32

SHEET 4 OF 20

SAN FRANCISCO OAKLAND BAY BRIDGE (OAKLAND-SAN FRANCISCO BAY BRIDGE)

SPANNING THE SAN FRANCISCO BAY SAN FRANCISCO CITY AND COUNTY CALIFORNIA

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JULIA KIM, 1999
TEXT BY: DAN PETERSON, AIA

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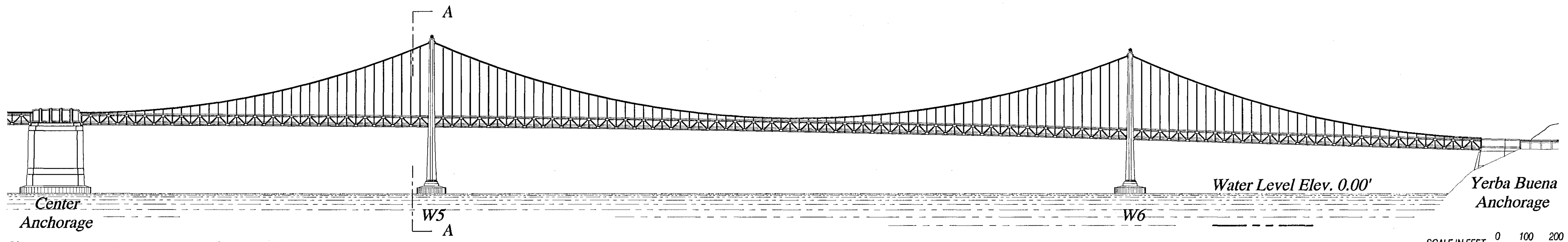
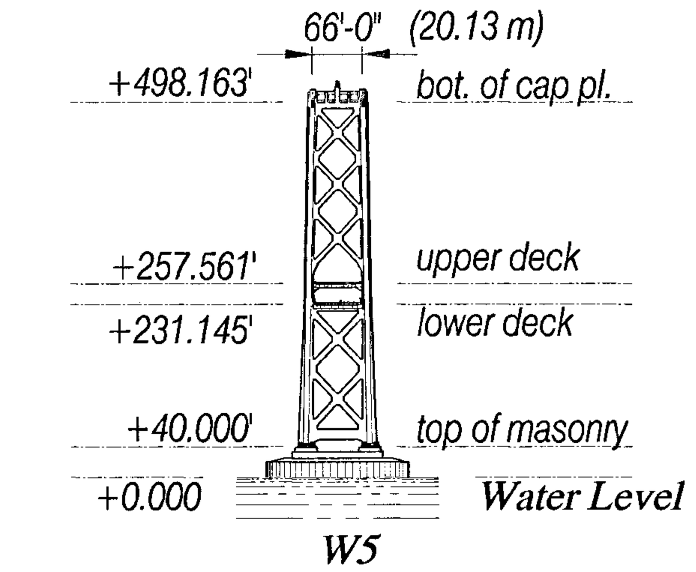




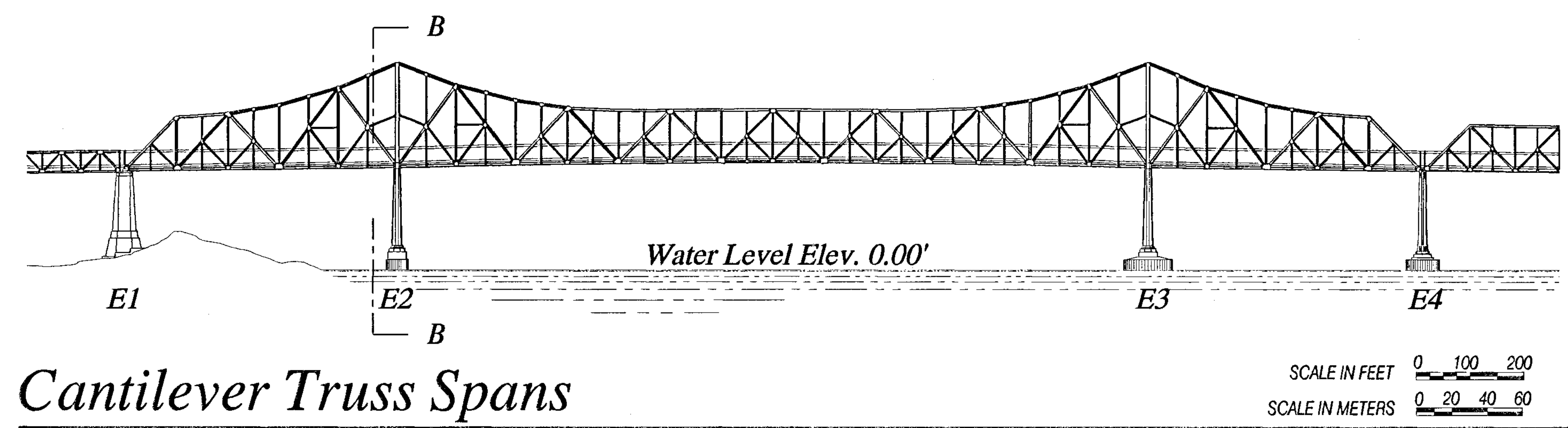
Suspension Bridge Spans

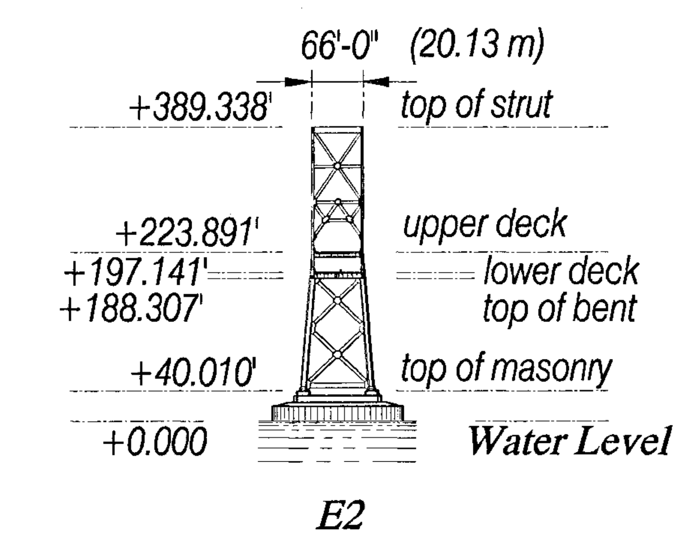
Section A-A

The main support members of the suspension bridge are parallel wire cables, 66 feet apart and 28-3/4 inches in diameter. The cables, which run the length of the bridge, are draped over towers, and secured at either end to anchorages. Suspenders, hung from the main cables, support the truss stiffened double-deck roadway system and are attached to truss panel points along the top chord. The weight of the bridge is supported by the cables, which are in tension and the towers which are in compression. The deck systems are supported on floor beams which are anchored to the panel points of the truss.

Truss Bridges-General Notes

The Truss bridges consist of parallel trusses, 66 feet apart. Cross members and bracing tie the top and bottom chords together creating a box-like cross section. The trusses are composed of a combination of straight members arranged in a triangular pattern. They are connected so that the stresses in the individual members, due to the loads on the whole truss, are direct stresses, either in compression or tension with little or no bending. The truss members are either riveted box sections made up of angles, plates, and lattice bracing, or high tensile strength eyebars with pin connections. All the trusses, except for the cantilever type, act as simple span beams supported by piers or towers at each end. Floor beams, connected at the truss panel points, support the deck system. The concrete slabs are supported on three systems of steel beams (transverse purlins, supported on longitudinal stringers, supported on transverse floor beams). The lower deck framing includes lateral bracing, while the upper deck floor system does not.

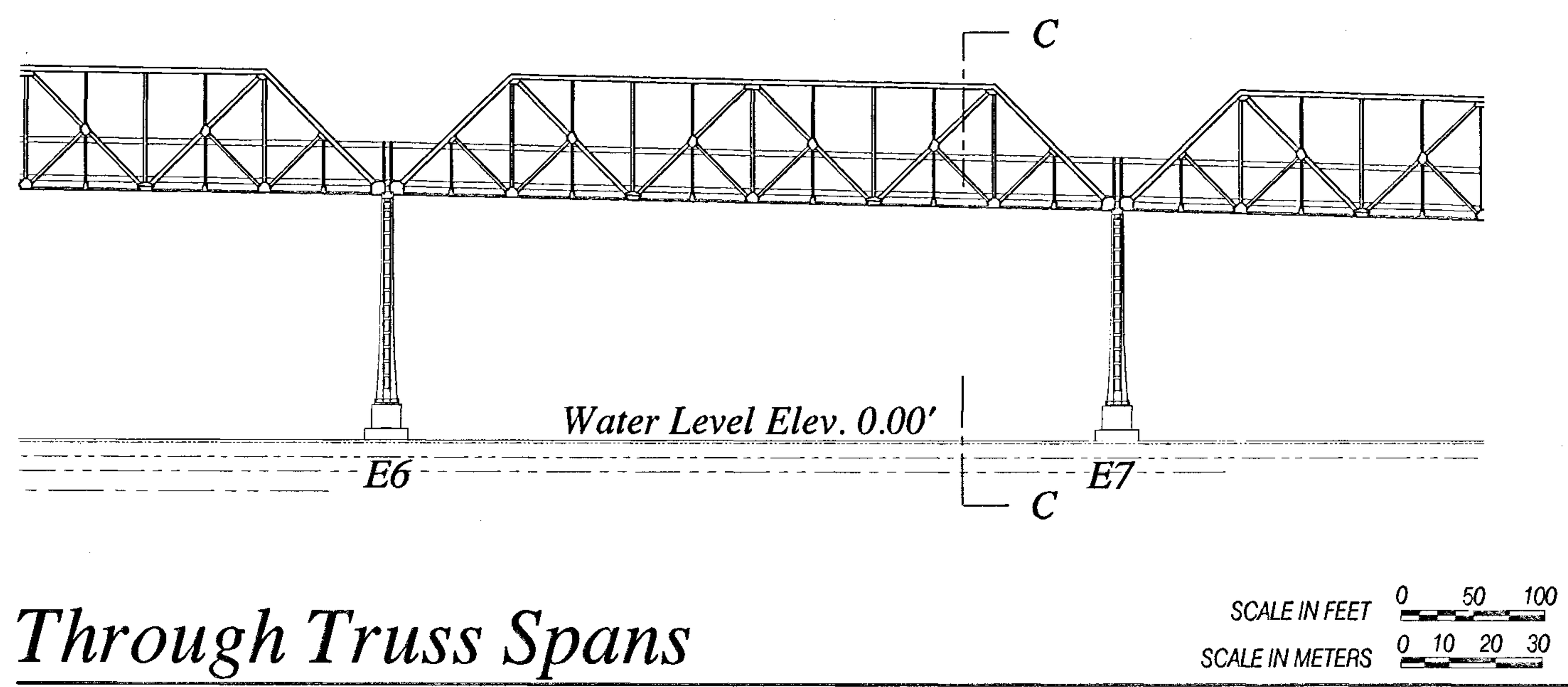


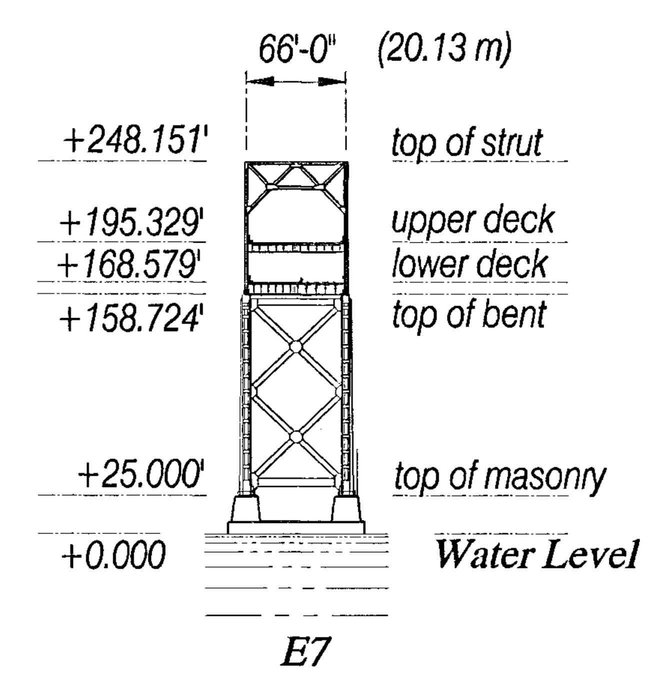


Cantilever Truss Spans

Section B-B

The cantilever bridge is composed of two arms that extend from opposite sides and a middle span which is suspended from the ends of each arm. The arms consist of an anchor arm supported by piers and the cantilever arm, which extends beyond the pier toward the middle of the span. Piers E1 and E4, at each end of the cantilever bridge, are designed to resist the uplift force of the anchor arms. Piers E2 and E3 are in compression, supporting the weight of the cantilever system.

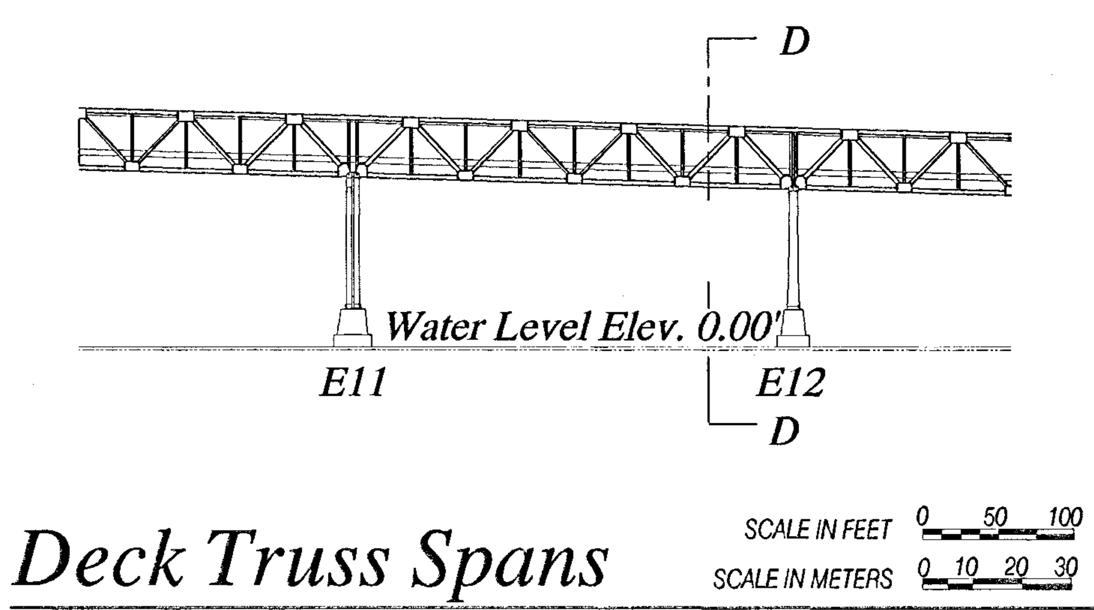


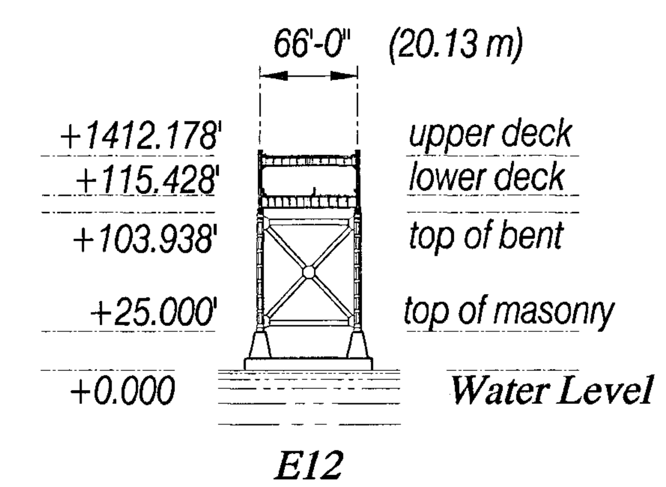


Through Truss Spans

Section C-C

There are five through truss spans of 504 feet center to center of the bearing pins. The through truss spans have both upper and lower decks within the truss framework, and sway bracing incorporated in the above-deck framing. Each span carries two decks of traffic on reinforced concrete slabs.





Deck Truss Spans

Section D-D

There are fourteen deck truss spans of 288 feet center to center of the bearing pins. The deck truss spans have the lower deck inside the truss framework and the upper deck on top of the truss framework. There is no sway bracing incorporated in the deck truss spans. Each span carries two decks of traffic on reinforced concrete slabs; each slab is supported on three systems of steel beams (transverse purlins, supported on longitudinal stringers, supported on transverse floor beams). The lower deck framing includes lateral bracing, while the upper deck floor system does not.

BRIDGE TYPES

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT, 1999 TEXT BY: DAN PETERSON, AIA
SAN FRANCISCO OAKLAND BAY BRIDGE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR
SAN FRANCISCO OAKLAND BAY BRIDGE (OAKLAND–SAN FRANCISCO BAY BRIDGE)
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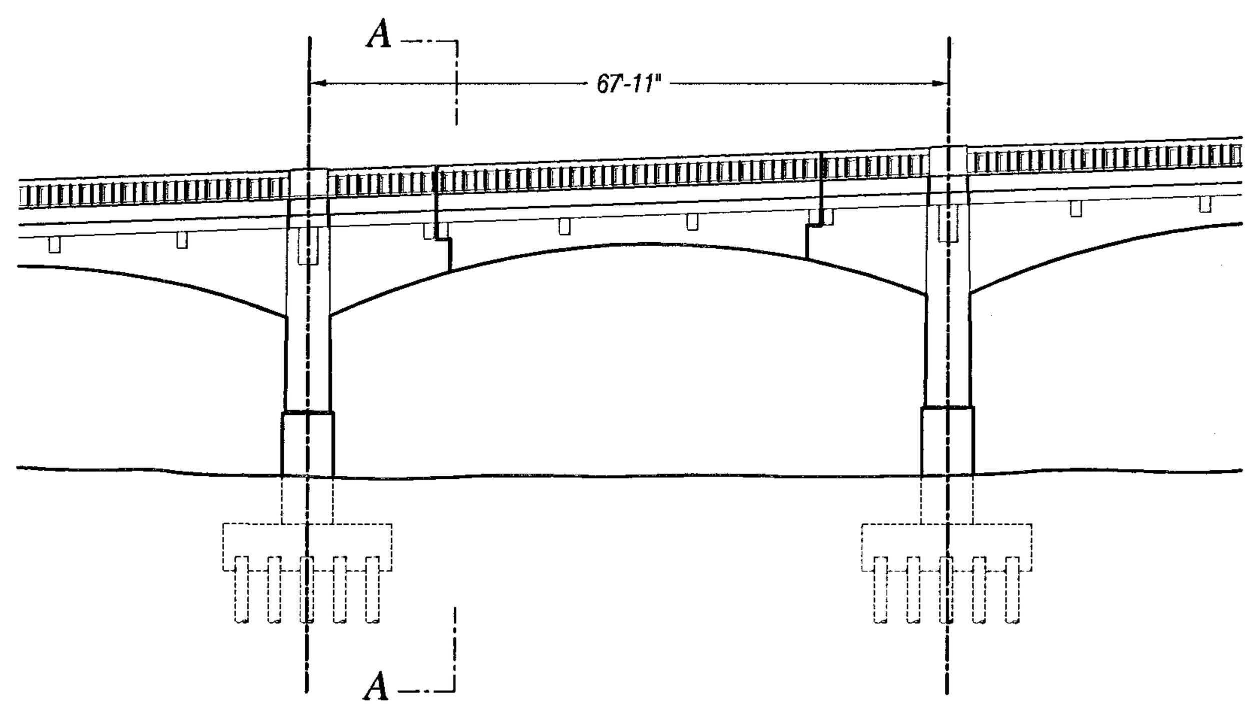
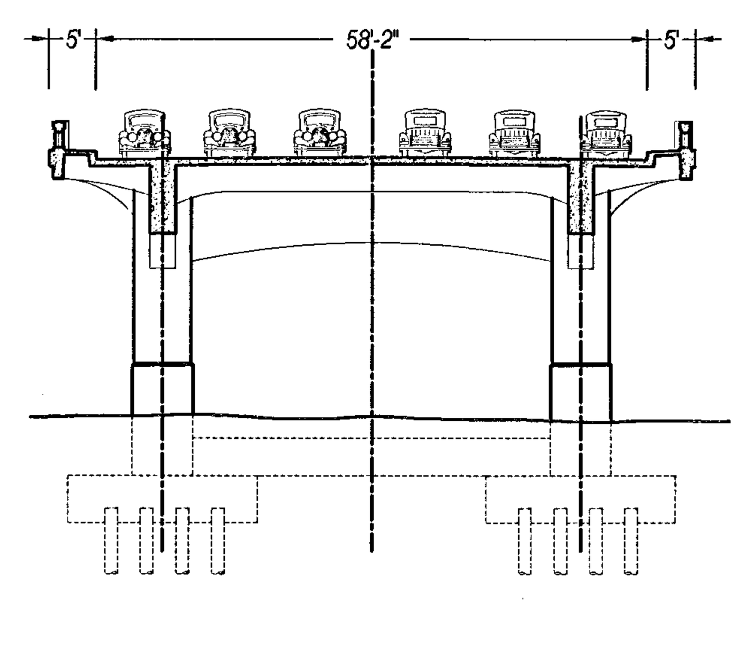
VIADUCTS

A viaduct is defined as a long bridge consisting of a series of short concrete or masonry spans supported on piers. Viaducts can also be a structure of steel girders and towers. The Viaducts of the San Francisco Oakland Bay Bridge occur at both, the San Francisco and the east bay approach, and also at both ends of the Yerba Buena Crossing. The original structures are mostly of reinforced concrete construction, with haunched concrete girders, carrying reinforced concrete slabs, supported on reinforced concrete multi-column bents. Foundations consist of spread footings on rock or timber piles to rock. Steel girders were used at certain locations, mainly in the Terminal ramps, where the elevated roadway crosses city streets. These steel spans shared concrete bents with adjacent concrete spans, and are supported at intermediate locations by steel bents.



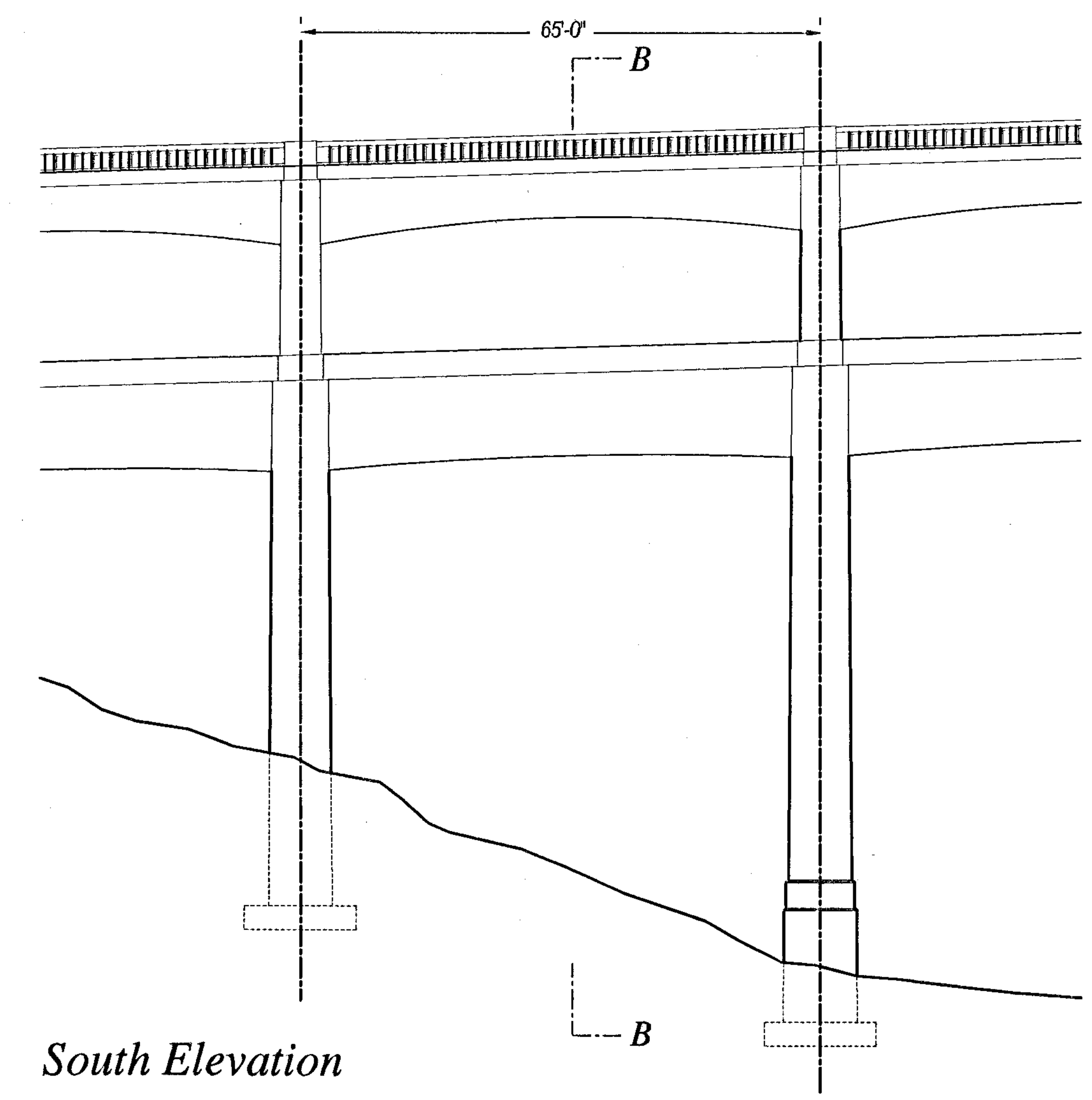
South Elevation



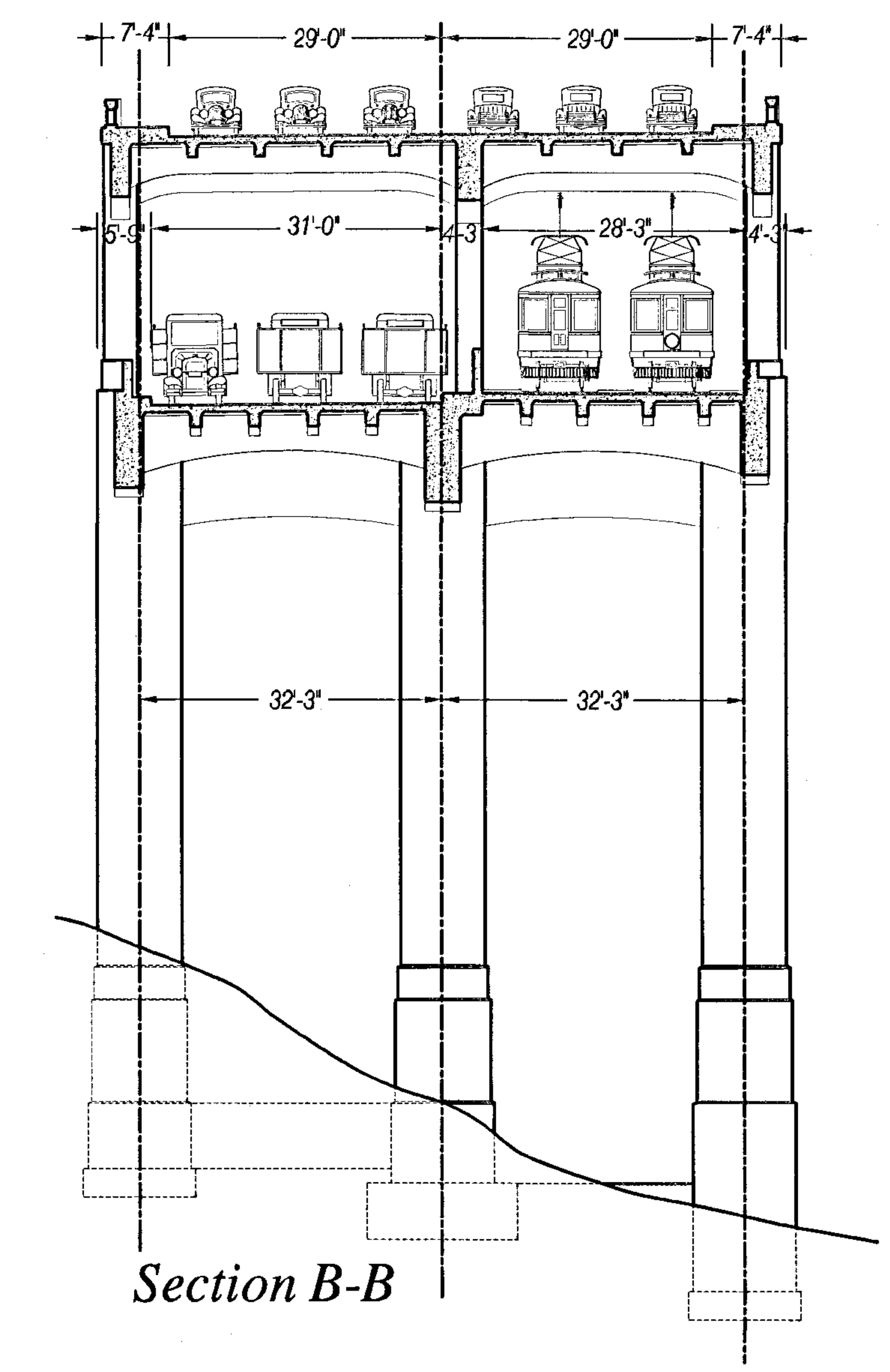
Section A-A

S.F. Viaduct - Single Deck Spans

The majority of the San Francisco approach was of single deck construction and provided automobile access to the upper deck of the bridge. The double deck viaduct occurs between Rincon Street (between Second and Third) and the San Francisco Anchorage. The lower section was used for truck and railroad traffic. Viaducts were also built for the bridge railway system to circulate to and from the bridge in a loop through the Transbay railway terminal. The original structures were mostly of reinforced concrete construction, with haunched concrete girders, carrying reinforced concrete slabs, supported on reinforced concrete column bents. Foundations consisted of timber piles or spread footings on rock. Steel girders were used at certain locations where the elevated roadway crossed over city streets. These steel spans shared concrete bents with adjacent concrete spans and were supported at intermediate locations by steel bents.

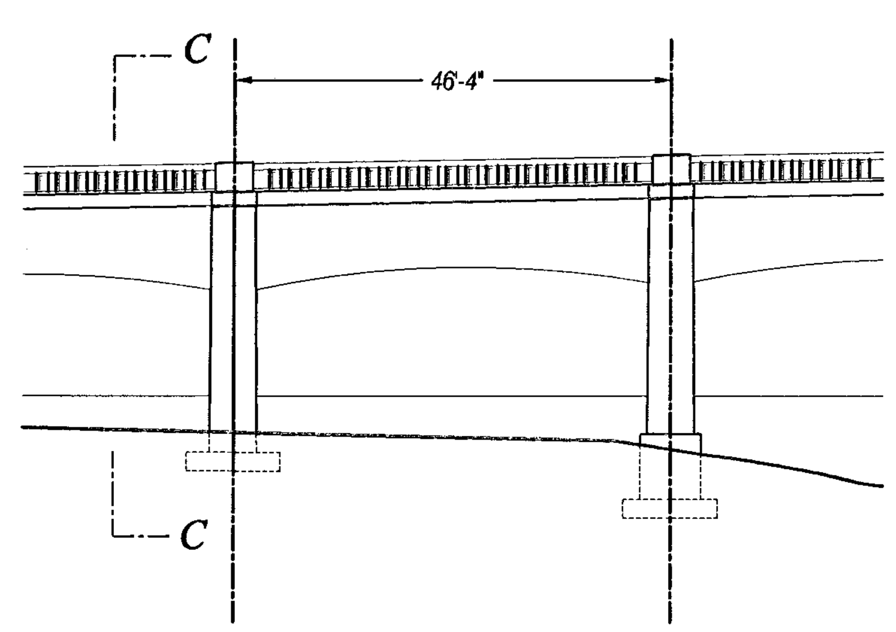


South Elevation

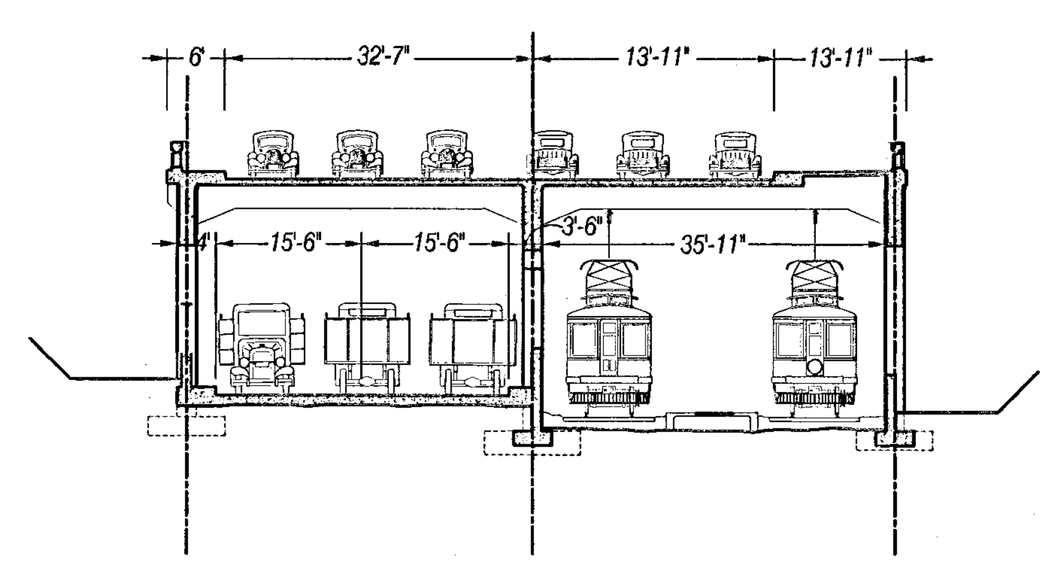


Section B-B

S.F. Viaduct - Double Deck Spans



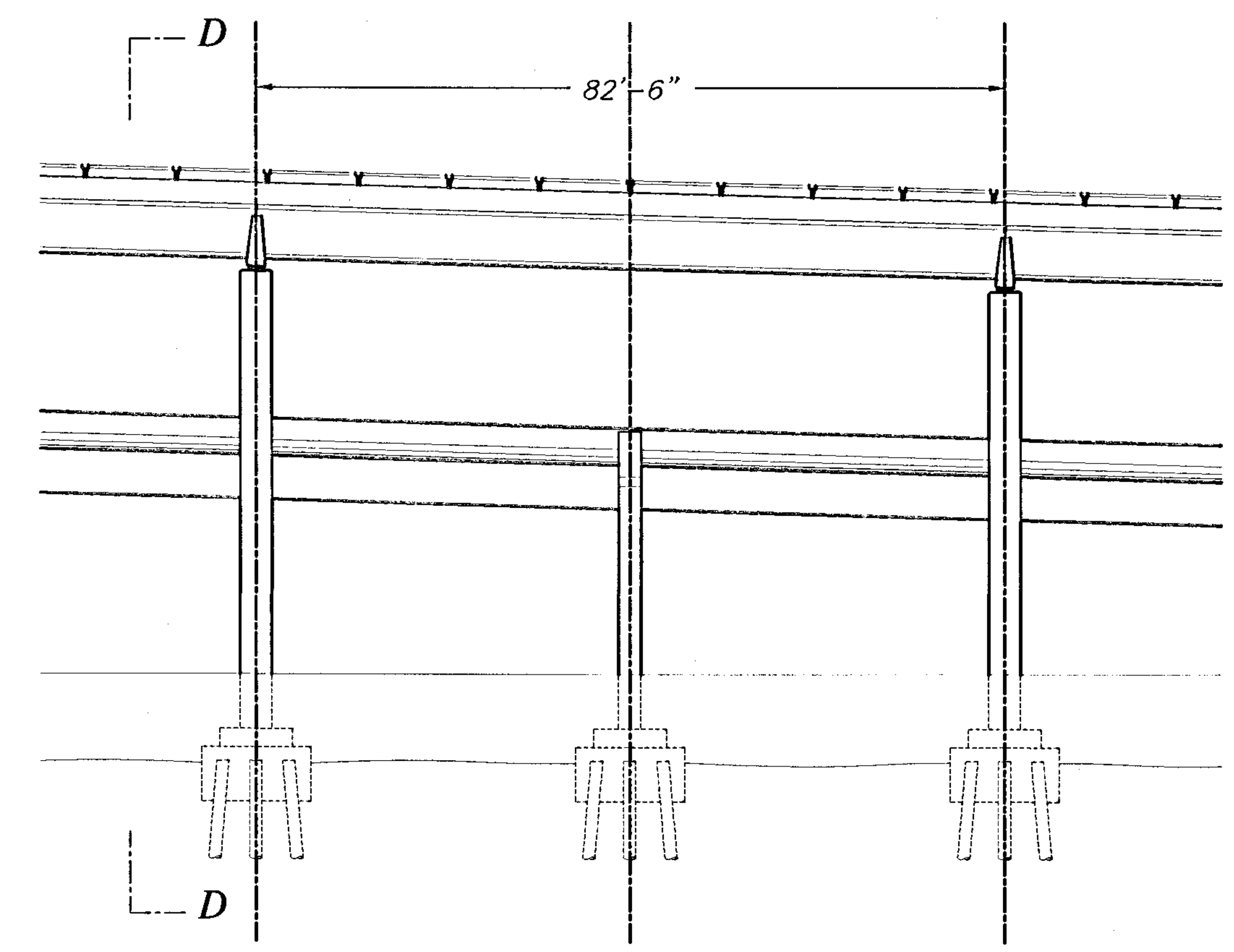
South Elevation



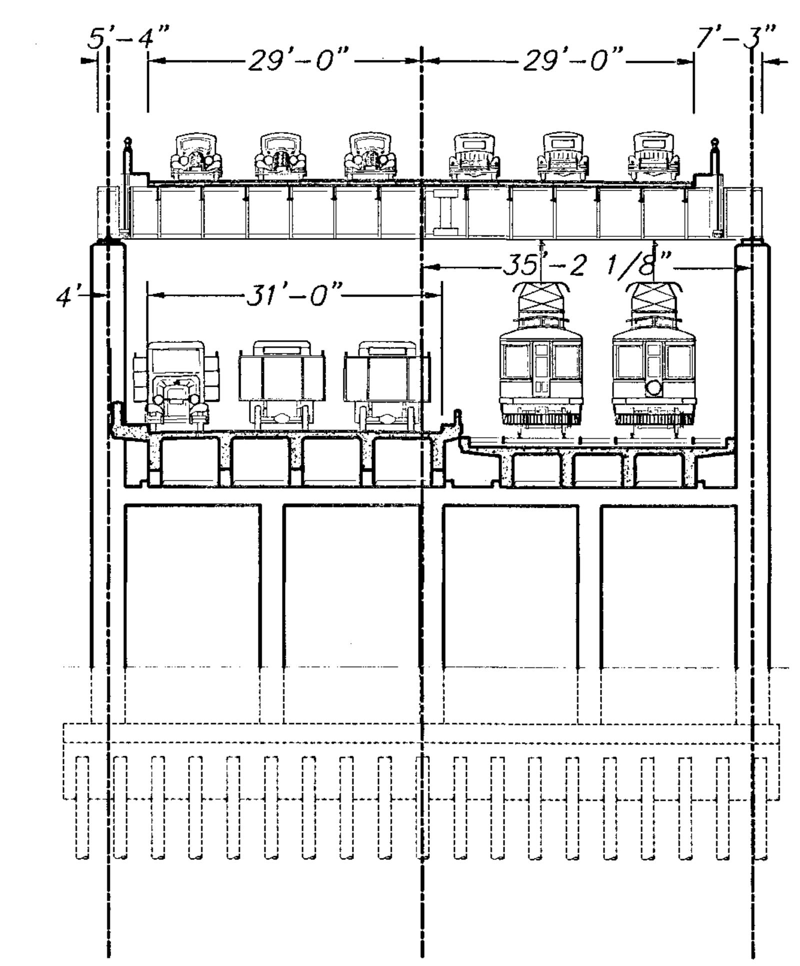
Section C-C

Yerba Buena Viaduct - Double Deck Spans

The viaducts on Yerba Buena Island were double deck concrete structures with portions of the lower deck sitting on grade. These viaducts extend west and east from the tunnel portals and connect to each of the bridge crossings.



South Elevation



Section D-D

East Bay Approach - Girder Spans

The viaducts of the East Bay approach were constructed of both steel and concrete. Concrete was used for the columns and lower deck system, and steel girders were used for the upper deck system.

VIADUCTS

SCALE IN FEET 0 8 16
SCALE IN METERS 0 1.6 3.2 4.8

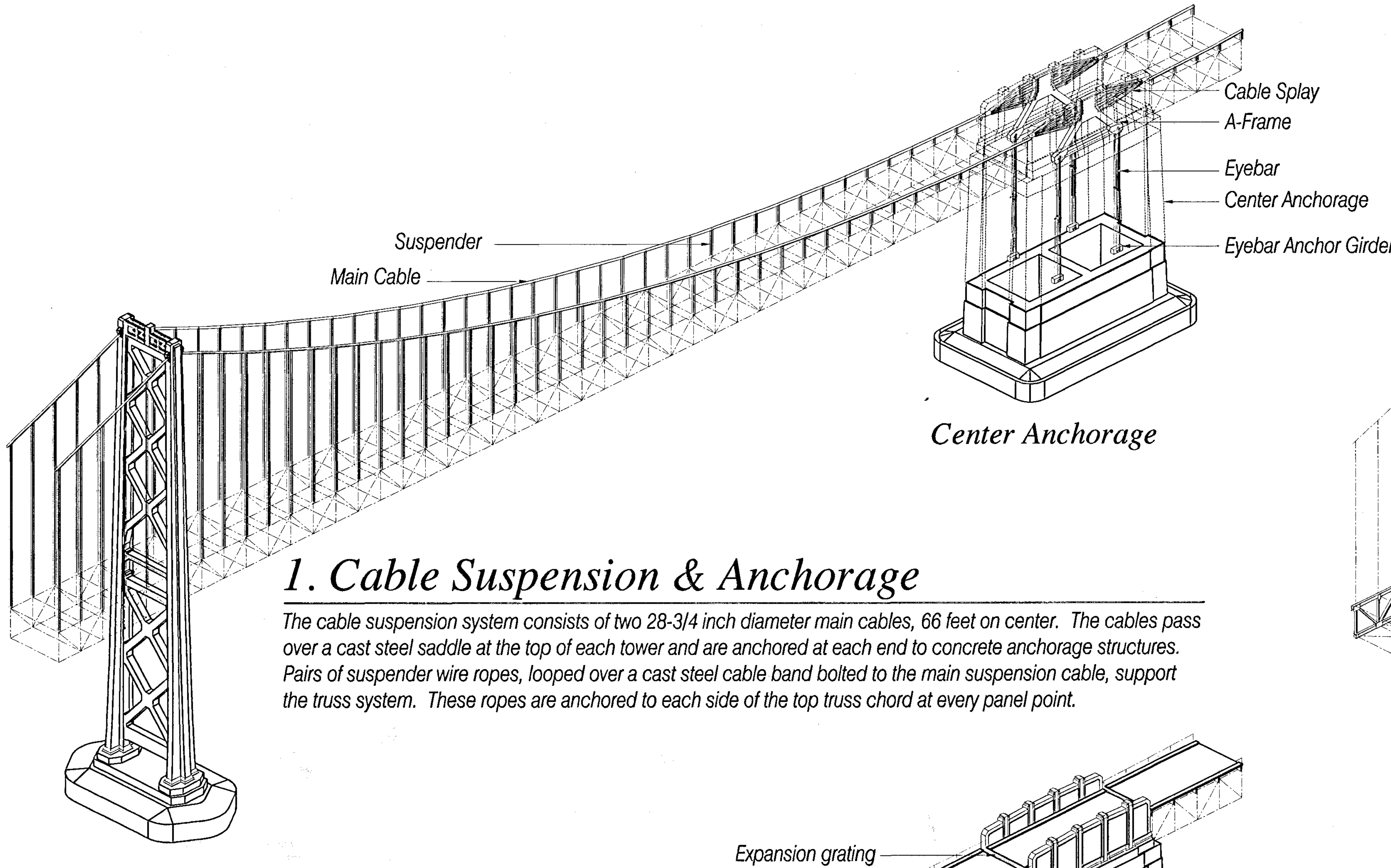
DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JULIA KIM, 1999 TEXT BY: DAN PETERSON, AIA

SAN FRANCISCO OAKLAND BAY BRIDGE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

SAN FRANCISCO OAKLAND BAY BRIDGE (OAKLAND-SAN FRANCISCO BAY BRIDGE)
SPANNING THE SAN FRANCISCO BAY SAN FRANCISCO CITY AND COUNTY CALIFORNIA

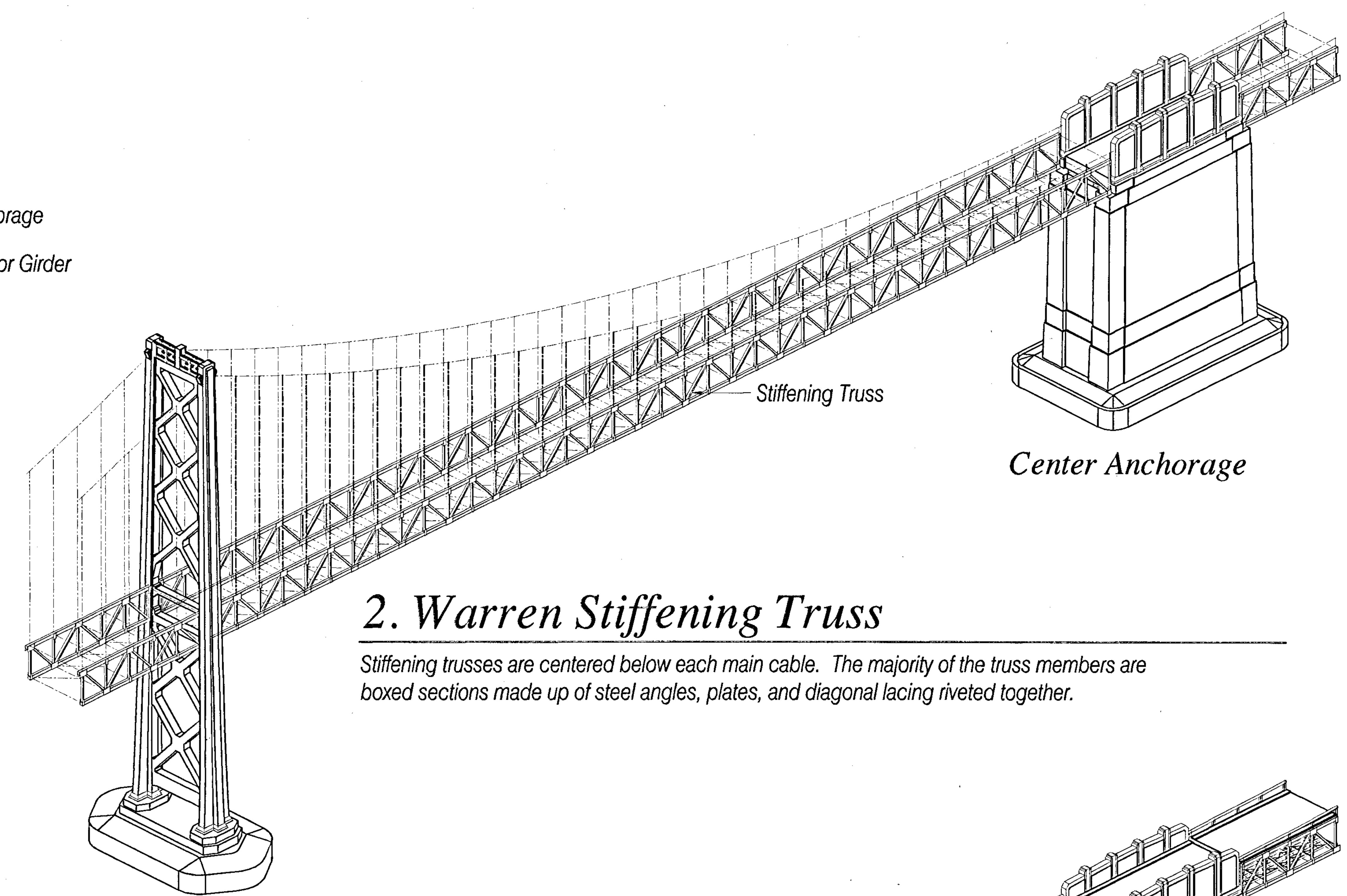
HISTORIC AMERICAN ENGINEERING RECORD CA-32

TRIM LINE



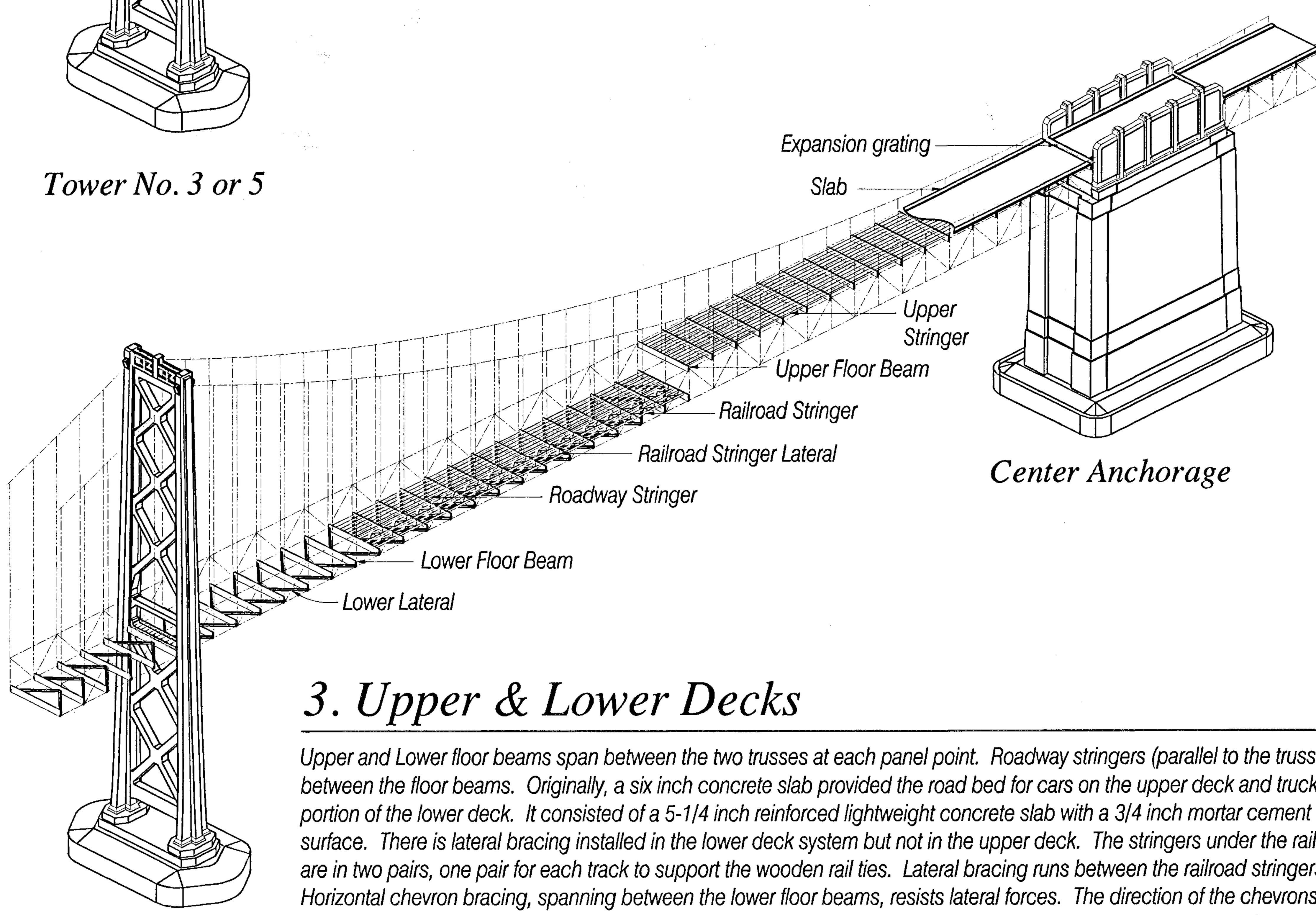
1. Cable Suspension & Anchorage

The cable suspension system consists of two 28-3/4 inch diameter main cables, 66 feet on center. The cables pass over a cast steel saddle at the top of each tower and are anchored at each end to concrete anchorage structures. Pairs of suspender wire ropes, looped over a cast steel cable band bolted to the main suspension cable, support the truss system. These ropes are anchored to each side of the top truss chord at every panel point.



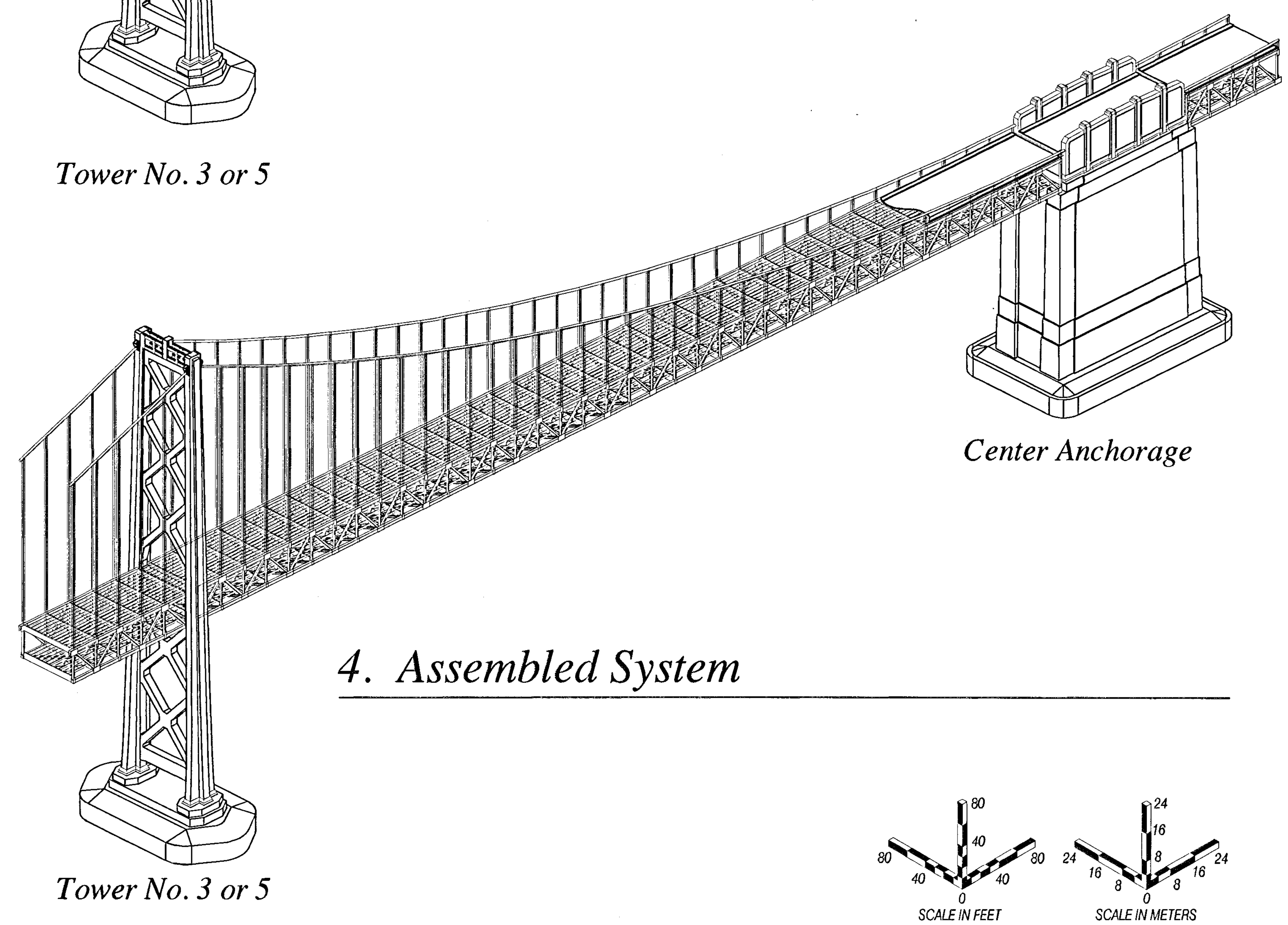
2. Warren Stiffening Truss

Stiffening trusses are centered below each main cable. The majority of the truss members are boxed sections made up of steel angles, plates, and diagonal lacing riveted together.



3. Upper & Lower Decks

Upper and Lower floor beams span between the two trusses at each panel point. Roadway stringers (parallel to the trusses) span between the floor beams. Originally, a six inch concrete slab provided the road bed for cars on the upper deck and trucks on a portion of the lower deck. It consisted of a 5-1/4 inch reinforced lightweight concrete slab with a 3/4 inch mortar cement wearing surface. There is lateral bracing installed in the lower deck system but not in the upper deck. The stringers under the rail system are in two pairs, one pair for each track to support the wooden rail ties. Lateral bracing runs between the railroad stringers. Horizontal chevron bracing, spanning between the lower floor beams, resists lateral forces. The direction of the chevrons changes at the midpoint of the span with the point of the chevron always pointing toward the nearest tower or anchorage.



4. Assembled System

SUSPENSION BRIDGE STRUCTURAL SYSTEMS

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JULIA KIM, 1999 TEXT BY: DAN PETERSON, AIA

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SAN FRANCISCO & ALAMEDA COUNTIES
CALIFORNIA

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SHEET 7 OF 20

HISTORIC AMERICAN ENGINEERING RECORD
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LIBRARY OF CONGRESS INDEX NUMBER

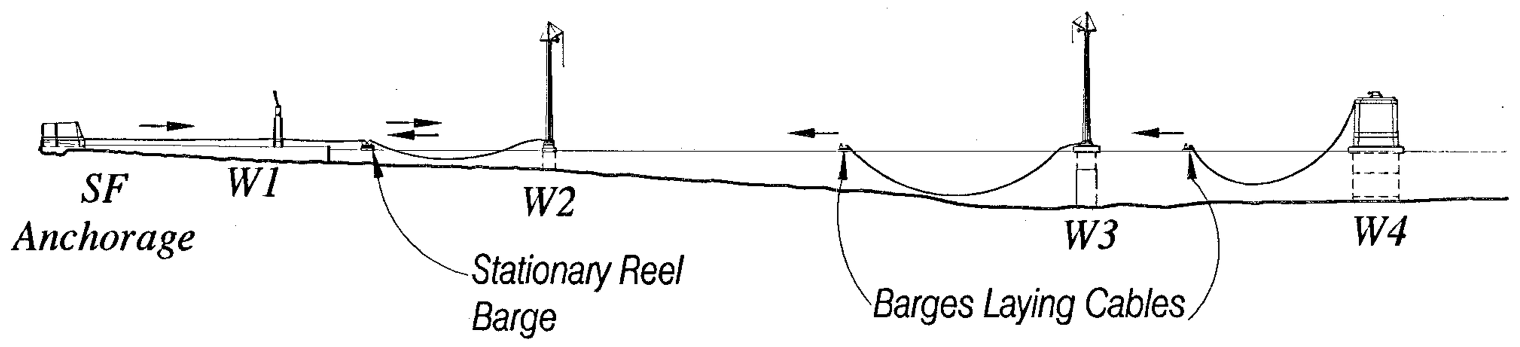
TRIM LINE

Cable Spinning Procedure

SCALE IN FEET 0 375 750
SCALE IN METERS 0 75 150 225

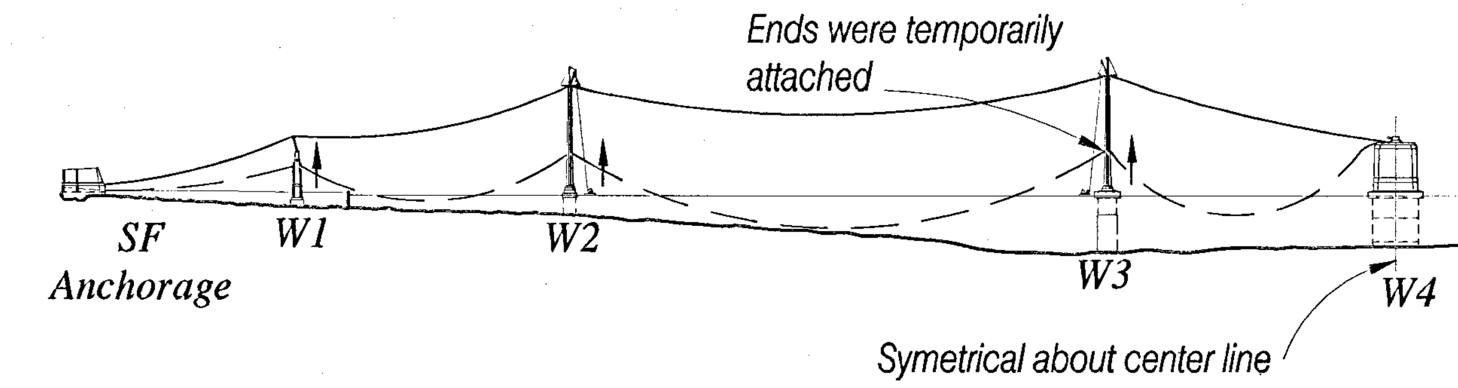
THESE CONSTRUCTION SEQUENCING DIAGRAMS ARE FOR THE SUSPENSION SPAN FROM THE SAN FRANCISCO ANCHORAGE TO ANCHORAGE W-4. THE CONSTRUCTION SEQUENCE FOR THE SUSPENSION SPAN FROM THE ANCHORAGE W-4 TO THE YERBA BUENA CABLE BENT AND ANCHORAGE IS SIMILAR.

ONCE THE ANCHORAGES, PIERS, ROCKER ARMS AND TOWERS WERE COMPLETED, THE CABLE SPINNING COULD BE STARTED. THE FIRST STEP WAS TO INSTALL A SYSTEM OF CATWALKS, A GANTRY SYSTEM TO SUPPORT THE TRAMWAY WIRE ROPES, AND STORM CABLES. TWO ROPES WERE REQUIRED ON EACH EDGE OF EACH CATWALK. THERE WERE TWO CATWALKS FOR EACH SECTION OF THE BRIDGE AND SIX CROSS BRIDGES THAT HELPED KEEP THE CATWALKS FROM SWINGING WHILE PROVIDING INTERMEDIATE ACCESS BETWEEN THE NORTH AND SOUTH CABLE OPERATIONS. THERE WAS ONE CROSS BRIDGE BETWEEN THE SAN FRANCISCO ANCHORAGE AND THE CABLE BENT AT W-1, ONE BETWEEN W-1 AND TOWER W-2, THREE BETWEEN TOWERS W-2 AND W-3, AND ONE BETWEEN TOWER W-3 AND THE CENTER ANCHORAGE W-4. THERE WERE ONLY 5 CROSS BRIDGES ON THE SUSPENSION BRIDGE BETWEEN PIER W-4 AND THE YERBA BUENA ANCHORAGE.



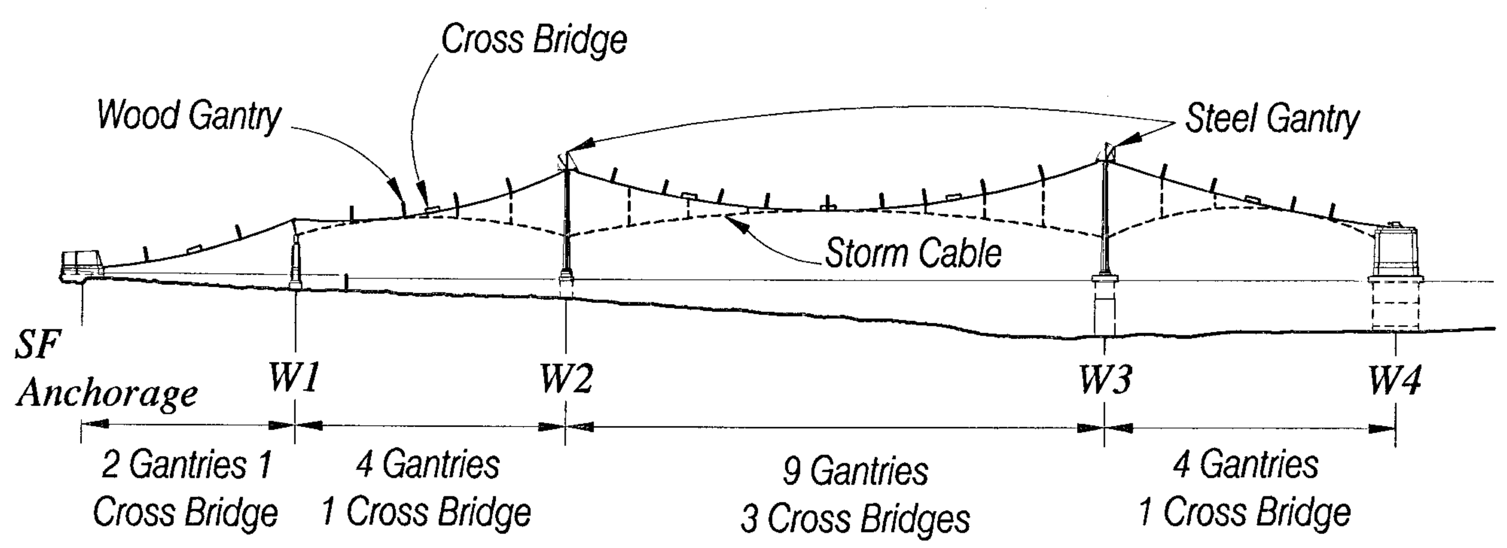
Stage 1: Laying Catwalk Cables

FIRST, CATWALK CABLES WERE LAYED OUT ALONG THE GROUND AND IN THE WATER. COILS OF CABLE WERE PLACED AT THE SAN FRANCISCO ANCHORAGE AND PULLED TO PIER W-1, WHERE THEY WERE TEMPORARILY ANCHORED. THEN A BARGE CONTAINING CABLE COILS LAID ANOTHER SET OF CABLES FROM THE BASE OF TOWER W-3 TO THE BASE OF TOWER W-2, ALLOWING THE CABLE TO SETTLE TO THE BAY BOTTOM. NEXT, THE CABLES WERE LAID FROM THE TOP OF PIER W-4 TO THE BASE OF TOWER W-3, ALLOWING THEM TO SETTLE TO THE BOTTOM. THE FINAL SET OF CABLES WAS THEN PULLED WEST TO TOWER W-1 FROM A BARGE ANCHORED NEAR SHORE AND THEN ACROSS CITY STREETS TO THE SAN FRANCISCO ANCHORAGE.



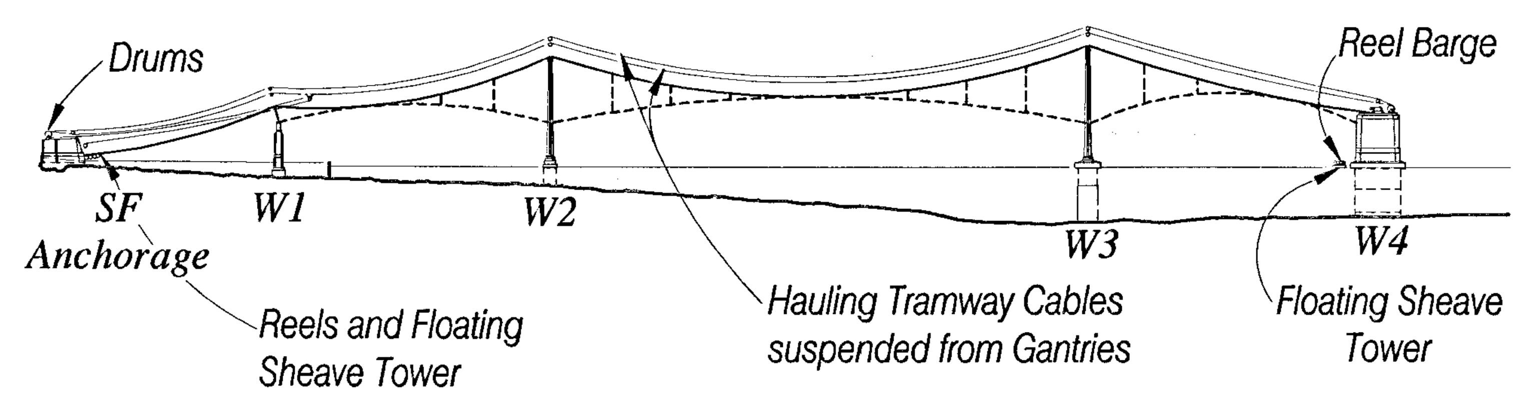
Stage 2: Raising Catwalk Cables

THE ENDS OF EACH CABLE SEGMENT WERE TEMPORARILY SECURED TOGETHER TO FORM ONE CONTINUOUS CABLE FROM ANCHORAGE TO ANCHORAGE. ONE CABLE AT A TIME WAS LIFTED TO THE TOP OF TOWERS W-2 AND W-3 SIMULTANEOUSLY AND TEMPORARILY PLACED IN THE CABLE SADDLE. THE CABLE AT CABLE BENT W-1 WAS ALSO LIFTED INTO PLACE. BY MEANS OF LARGE COME-ALONGS AND SETS OF WIRE ROPE TACKLE, EACH CABLE END WAS SEPARATED AND MOVED FROM THE CABLE SADDLE TO FINAL ATTACHMENTS ON THE TOWERS. THE SAG IN THE CATWALK CABLE WAS ADJUSTED TO BE THREE FEET BELOW BUT WITH THE SAME SAG AS THE FINAL SUSPENSION CABLE.



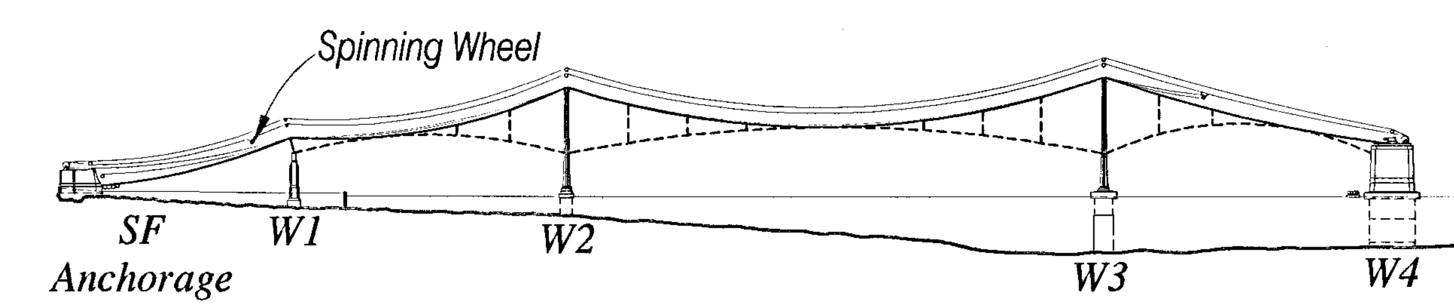
Stage 3: Installing Catwalk, Gantries and Storm Cables

THE CATWALK FLOOR BEAMS AND CROSS BRIDGES WERE INSTALLED BY LIFTING THEM TO THE TOP OF THE TOWERS AND SLIDING THEM DOWN THE CATWALK CABLES. THE SECTION FROM THE SAN FRANCISCO ANCHORAGE TO BENT W-1 WAS DONE FROM THE ANCHORAGE AND PULLED UP THE CABLES. THE CROSS BRIDGE IN THE MIDDLE OF THE MAIN SPAN WAS LIFTED TO THE TOP OF THE TOWER AND ROLLED DOWN THE CATWALK CABLES. THE FLOOR BEAMS FOR A 100 FOOT SECTION OF CATWALK WERE PREFABRICATED ON THE GROUND USING STRIPS OF CHAIN LINK FENCE TO MAINTAIN A 10 FOOT BEAM SPACING WHEN STRETCHED OUT. THESE 100 FOOT SECTIONS, FOLDED UP, WERE LIFTED TO THE TOPS OF THE TOWERS AND LAID ON THE CATWALK CABLES. ONCE THE NUMBER OF SECTIONS REQUIRED BETWEEN CROSS BRIDGES WAS ASSEMBLED, THEY WERE STRETCHED OUT, DRAGGED DOWN THE CABLES AND BOLTED INTO POSITION. THE FLOOR BEAMS WERE FASTENED TO THE CABLES WITH A BOLTED CONNECTION THAT ALLOWED THEM TO SLIDE BEFORE THE BOLTS WERE SECURED. EACH 100 FOOT SECTION WAS CONNECTED TOGETHER WITH STRIPS OF CHAIN LINK FENCE. THE HANDRAIL POSTS, WHICH SUPPORTED THE HAND ROPE, AND POWER AND PHONE LINES, WERE PREFABRICATED AND THEN ATTACHED TO THE CATWALK FLOOR BEAMS. THE STORM CABLES WERE THEN INSTALLED BY LOWERING THEM OFF THE CATWALK. THE VERTICAL CABLES FOR THE STORM CABLE SYSTEM WERE ATTACHED TO THE FLOOR BEAMS. ONE END OF EACH MAIN STORM CABLE WAS FIXED AND THE OTHER END WAS ATTACHED TO A SET OF WIRE ROPE TACKLE WITH A COUNTERWEIGHT FROM THE MAIN LEAD LINE. THIS COUNTERWEIGHT ARRANGEMENT ALLOWED MOVEMENT UP AND DOWN AS A RESULT OF TEMPERATURE, WIND AND LIVE LOAD VARIATIONS OR VARIATIONS IN SPAN LENGTH AS THE ERECTION PROCEEDED. THIS ALSO PERMITTED SLIGHT ADJUSTMENT OF THE CATWALK ELEVATION WITHIN THE SPAN.



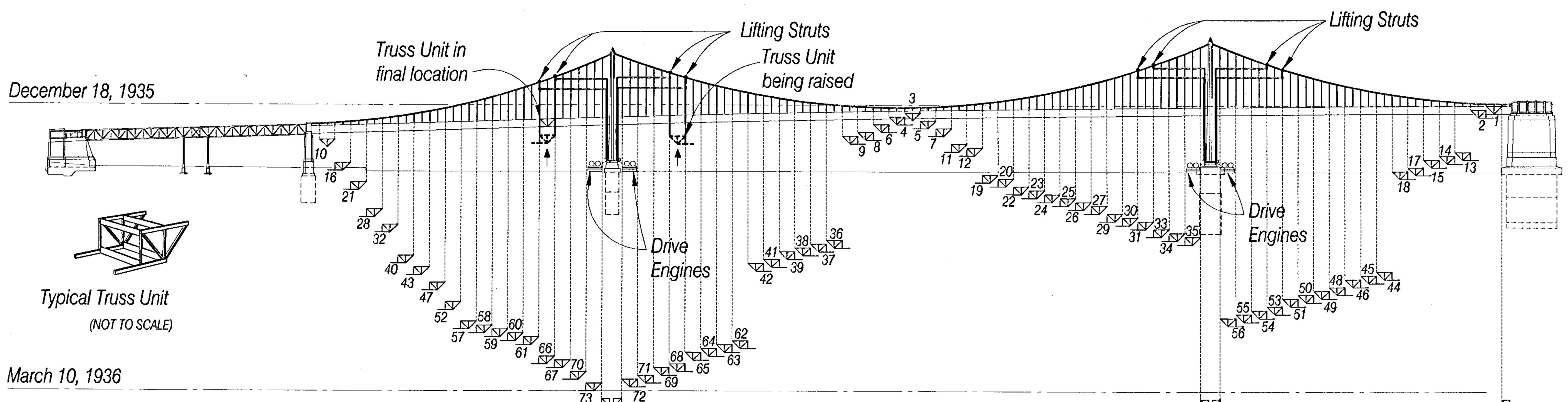
Stage 4: Spinning Wheels Leaving Anchorages

THE TRAMWAY CABLES AND WHEELS USED TO LAY THE WIRES OF THE MAIN CABLE WERE INSTALLED AND USED TO TRANSPORT THE WOODEN GALLOWS FRAMES DOWN FROM THE TOWER AND INTO POSITION ALONG THE CATWALKS. THE GALLOWS HAD PROVISIONS TO LIFT THE WIRE GROUPINGS TO AND FROM TEMPORARY CABLE SPLAY CASTINGS ALONG THE CATWALK USING HAND WINCHES. THE SPINNING EQUIPMENT CONSISTED OF A HAULING ROPE DRIVE SYSTEM, TWO SETS OF REEL STANDS, AND TWO FLOATING SHEAVE TOWERS FOR EACH MAIN CABLE. THE HAULING ROPE WAS 7/8 INCH IN DIAMETER AND WAS CONTINUOUS FROM ONE ANCHORAGE TO THE OTHER AND BACK AGAIN. THE ROPE PASSED AROUND A 7 FOOT DIAMETER WHEEL AT EACH ANCHORAGE ALLOWING THE HAULING ROPE TO RUN ALONG THE SIDES OF THE CATWALK. EACH OF THE WHEELS WAS DRIVEN BY A 75 H.P. VARIABLE SPEED MOTOR CAPABLE OF MOVING THE TRAM CABLE AT A SPEED UP TO 600 FEET PER MINUTE. THE REEL STANDS HELD 8 REELS OF WIRE AND A REEL ACCELERATOR THAT WOULD BRING THE REEL SPEED UP TO THE NECESSARY SPEED TO REEL OUT 1,200 FEET OF WIRE PER MINUTE. THE FLOATING SHEAVE TOWER WAS RIGGED WITH A NUMBER OF SHEAVES WITH COUNTER WEIGHTS WHICH KEPT A CONSTANT TENSION ON THE WIRE BEING REELED OUT. TWO SPINNING WHEELS WERE ATTACHED TO THE HAULING ROPES, ONE FOR EACH DIRECTION, WITH A "V" SHAPED FRAME (SEE DETAIL). EACH WHEEL CONTAINED TWO GROOVES WHICH PERMITTED LAYING DOWN FOUR WIRES AT A TIME. WITH THE TWO SPINNING WHEELS GOING IN OPPOSITE DIRECTIONS AT THE SAME TIME, EIGHT STRAND WIRES COULD BE LAID FOR EACH PASS. THE HAULING CABLES WERE 7 FEET APART (THE DIAMETER OF THE DRIVE WHEELS) AND PASSED ALONG THE SIDES OF THE CATWALK. THIS PERMITTED LAYING WIRE FOR TWO STRANDS AT A TIME. THE MAIN CABLES WERE MADE UP OF 37 STRANDS WHICH CONTAINED 472 WIRES EACH FOR A TOTAL OF 17,464 WIRES.



Stage 5: Spinning Wheels Arriving at Anchorages

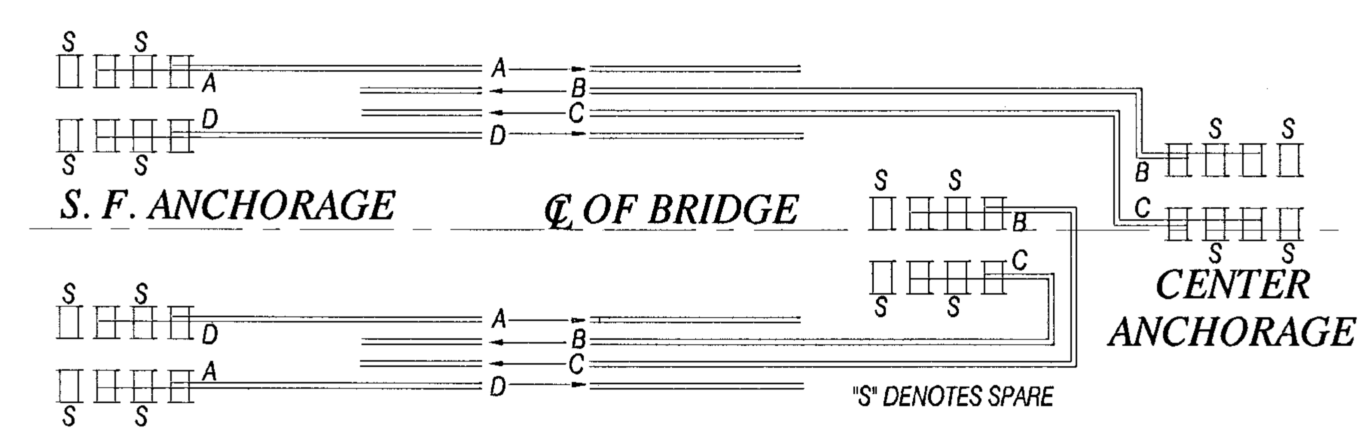
EIGHT REELS OF WIRE, FOUR FOR EACH SPINNING WHEEL, WERE LOCATED AT THE ANCHORAGES FOR EACH CABLE. FOUR REELS, TWO FOR EACH SPINNING WHEEL, SERVED AS SPARES. EACH SPINNING WHEEL DREW WIRE FROM TWO REELS AT A TIME. THE SPINNING WHEEL WAS STOPPED WHEN IT REACHED THE OPPOSITE ANCHORAGE, THE WIRES WERE TRANSFERRED TO THE STRAND SHOE, AND A NEW WIRE LOOP WAS ATTACHED TO THE SPINNING WHEEL FOR THE RETURN TRIP. IN OTHER WORDS, ON ONE PASS ONE OF THE SPINNING WHEELS WOULD PULL WIRE FROM THE GROUP "A" REELS AND THE OTHER SPINNING WHEEL , GOING IN THE OPPOSITE DIRECTION WOULD PULL WIRE FROM THE "B" GROUP OF REELS. WHEN THE WHEELS REACHED AN ANCHORAGE, THE WIRES FROM THE "A" REELS WOULD BE ATTACHED TO THE STRAND SHOES AND THE WIRE FROM THE "D" REELS WOULD BE ATTACHED TO THE SPINNING WHEEL. AT THE OPPOSITE END, THE WIRES FROM THE "B" REELS WOULD BE ATTACHED TO THE STRAND SHOES AND THE WIRE FROM THE "C" REELS WOULD BE ATTACHED TO THE SPINNING WHEEL. THIS PROCESS WAS REPEATED EACH TIME THE SPINNING WHEELS REACHED THE ANCHORAGES.



Suspended Structure Erection Sequence

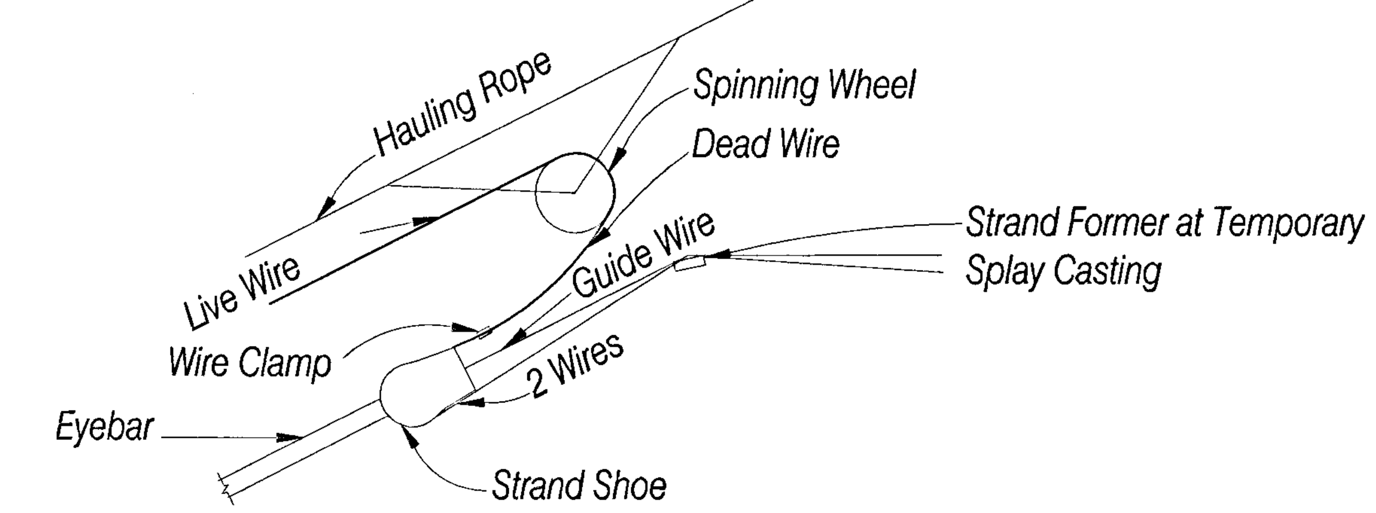
SCALE IN FEET 0 150 300
SCALE IN METERS 0 30 60 90

AFTER THE CABLE WAS COMPLETED, CAST CABLE BANDS AND SUSPENDER ROPES WERE INSTALLED TO SUPPORT THE BRIDGE TRUSS SYSTEM. THE BRIDGE TRUSSES WERE RAISED USING A TRAVELING LIFT STRUT THAT SPANNED THE CABLES. THE LIFTING STRUT CONTAINED 12 INCH DIAMETER CONCAVE WHEELS THAT FIT OVER THE CABLE AND PERMITTED IT TO BE ROLLED ON THE CABLE. THE LIFTING STRUT CONTAINED SHEAVES FOR THE LIFTING CABLE. THESE SHEAVES WERE DRIVEN BY A PROPELLER SHAFT AND CONTINUOUS CABLES WHICH EXTENDED DOWN TO THE BASE OF THE TOWERS WHERE THE DRIVE ENGINES WERE LOCATED. FOUR ENGINES WERE USED TO DRIVE FOUR LIFTING POINTS, TWO BELOW EACH CABLE. SEPARATE ENGINES AT THE BASE OF THE TOWERS WERE USED TO MOVE THE TRAVELING LIFT STRUT. TO KEEP THE SAG AND FORCES IN THE MAIN CABLE BALANCED, THE TRUSS UNITS WERE LIFTED IN A SPECIFIC ORDER STARTING FROM THE CENTER OF THE MAIN SPAN AND THE END OF THE END SPANS (W-1, W-4, AND THE YERBA BUENA ANCHORAGE) AND WORKING TOWARD THE TOWERS AS SHOWN IN THE NUMBERED SEQUENCE ABOVE.



Cable Spinning Diagram

NOT TO SCALE



Cable Spinning Detail

NOT TO SCALE

SUSPENSION BRIDGE CONSTRUCTION

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JOSEPH ATALLA, 1999 TEXT BY: DAN PETERSON, AIA

SAN FRANCISCO OAKLAND BAY BRIDGE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
NATIONAL PARK SERVICE
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SAN FRANCISCO OAKLAND BAY BRIDGE (OAKLAND–SAN FRANCISCO BAY BRIDGE)
SPANNING THE SAN FRANCISCO BAY SAN FRANCISCO CITY AND COUNTY CALIFORNIA

SHEET 8 OF 20

HISTORIC AMERICAN ENGINEERING RECORD CA-32

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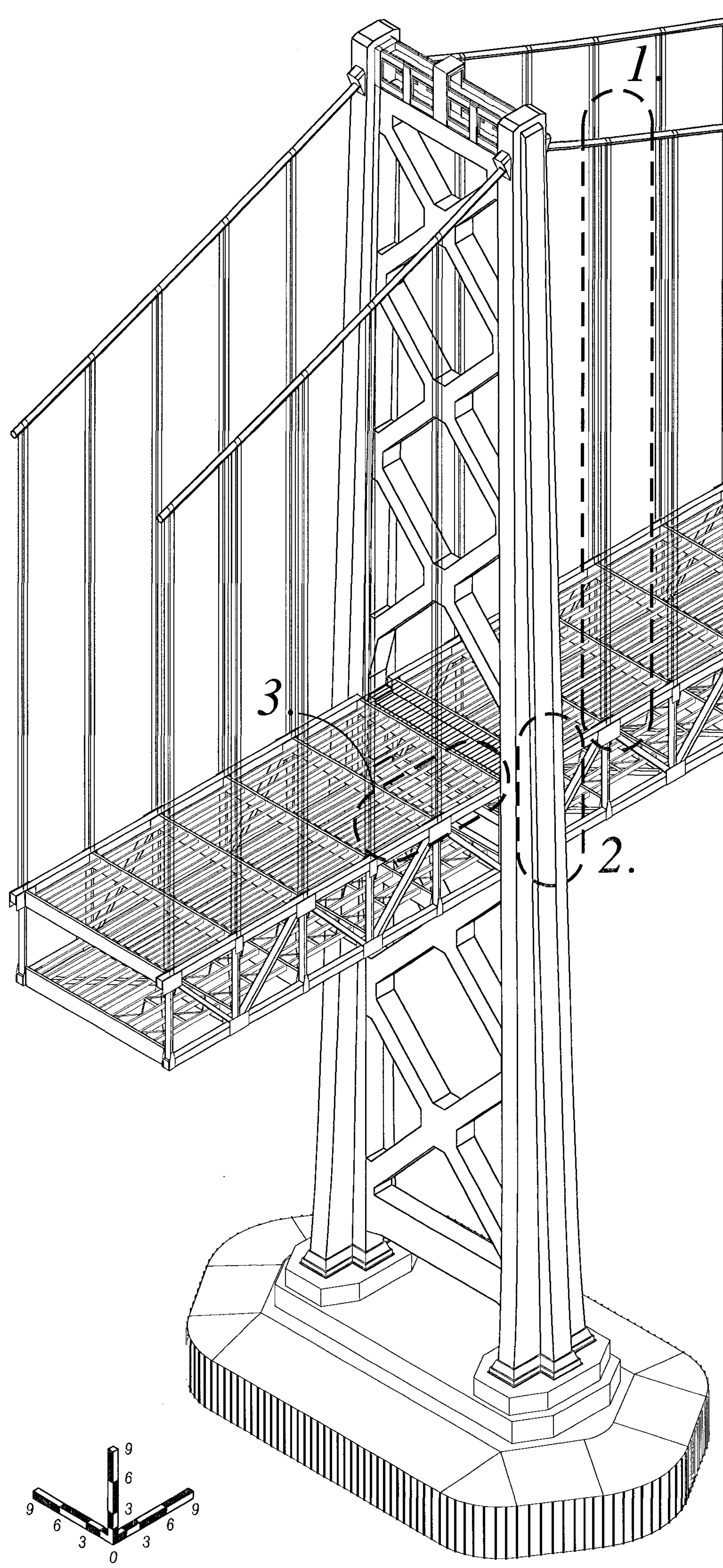
TRIM LINE



1. Truss Suspension

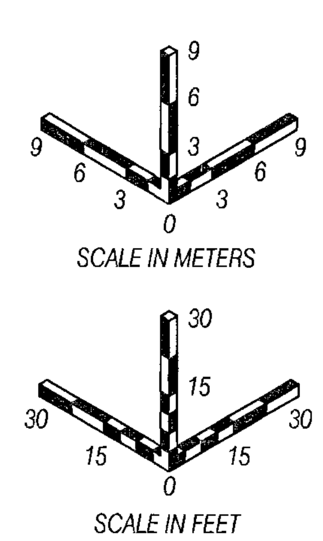
At each suspender location (Inset 1), the wires of the cable are clamped together with a cast steel cable band that is bolted together around the cable. Friction due to the clamping force prevents the cable bands from slipping down the cables. Grooves in the cable band provide support for the suspender ropes, which are looped over the cable band to support the truss. At the lower ends of the suspenders, the suspender ropes are connected to sockets using molten zinc poured into the open socket; the sockets are then secured within steel plate anchorages to support the trusses.

2. The Rocker Arms

The rocker arms exist in pairs on each tower shaft - for a total of four such links on each tower, immediately beneath the trusses. A pair of rocker arms on one tower shaft is shown in Inset 2. The top of each link is connected to the lower end panel point of the truss; the bottom of each link is connected to a plate assembly that is part of the inside leg of the cruciform cross-section of the tower shafts. These top and bottom connections are pivoted, using bearing pins that are oriented in the direction of the transverse axis of the bridge. The rocker arms support the weight of the last panel of each truss, as compression links. Under imposed loads and environmental conditions - wind, earthquake, traffic, temperature change, etc. - they prevent the ends of the trusses from moving vertically relative to the tower, and also from twisting as a unit about the longitudinal (east-west) axis of the bridge. The articulated rocker arms, with bearing pivot pins at each end, allow the bridge deck to move in the longitudinal direction (both rocker arms rotate in and out together), to rotate about a transverse axis as caused by vertical loads (the rocker arms rotate only slightly, while the truss pivots about the upper bearing pins), and also to rotate about a vertical axis as caused by lateral loads (one arm rotates inward, the other arm rotates outward as the trusses bend sideways).

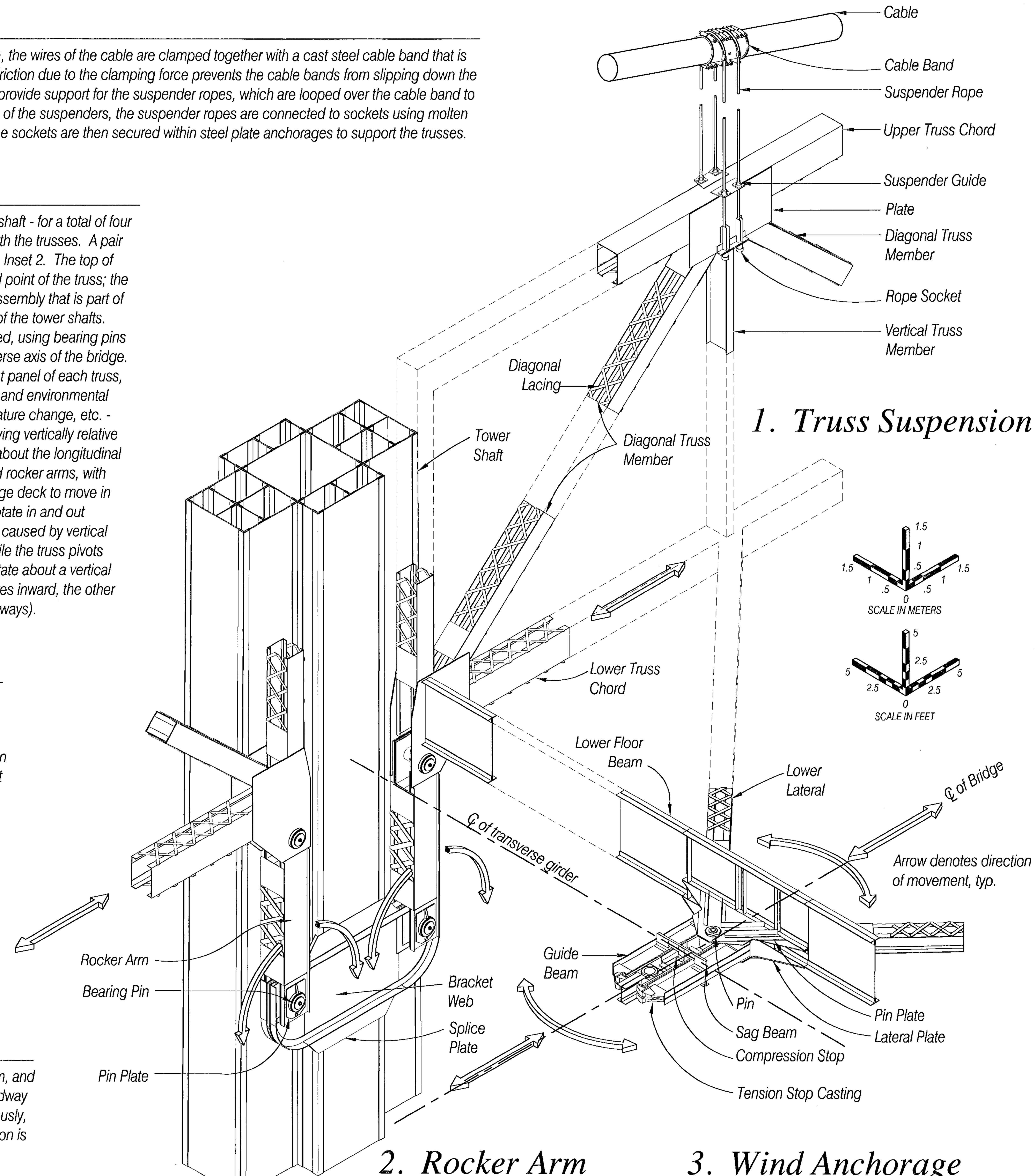
3. The Wind Anchorage

The wind anchorage system exists on the centerline of the tower and is connected to the lower lateral bracing of the trusses and to the transverse framing girder (not shown) that is part of the tower bracing just beneath the lower roadway. These anchorages, shown in Inset 3, transfer lateral loads on the trusses to the towers without allowing lateral (N-S) movement. The last panel of lower lateral bracing below the lower deck projects through the last lower floor beam. A vertically oriented pin at the apex of the lateral members engages a longitudinal slot between fabricated steel shapes that is connected to the tower framing. The system resists transverse lateral loads without allowing transverse movement by forcing the pins to engage the edges of the slots. The configuration of the slots allows the pin to move freely and allows relative longitudinal movement between the trusses and the towers. The ends of the slots are closed so that in the event of extreme longitudinal loads, the pins can never break free of the slots.



Suspension Tower Details

Each of the towers and anchorages of the West Bay Crossing suspension bridge provides support for the cable system, and articulated support of the trusses. The articulation allows for thermal expansion and contraction of the trusses and roadway slabs by allowing free movement in three directions - longitudinal, transverse rotation, and vertical rotation. Simultaneously, vertical, transverse, and torsional movements are restrained at each end of the suspended truss. This type of articulation is common to suspension bridges of the Bay Bridge era, although the particular details are unique to this structure.



SUSPENSION BRIDGE DETAILS

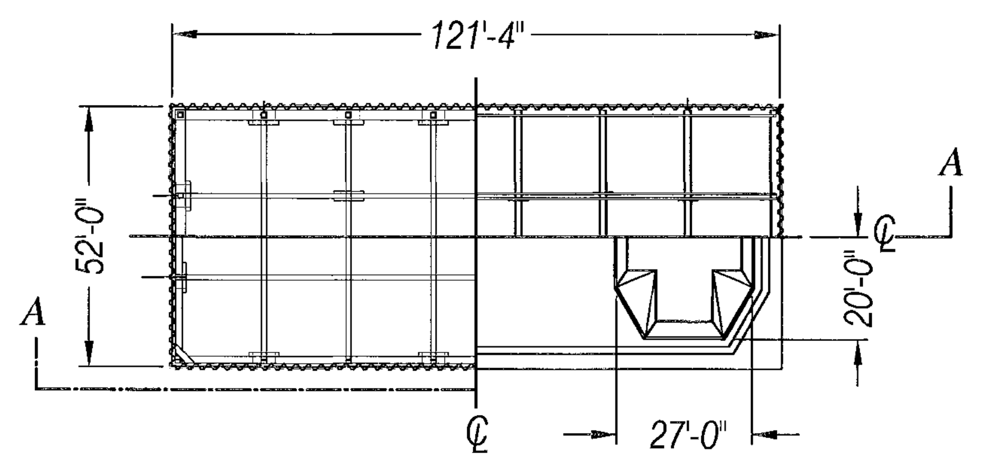
DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JULIA KIM, 1999 TEXT BY: MARK KETCHUM, PH. D, P.E.

SAN FRANCISCO OAKLAND BAY BRIDGE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

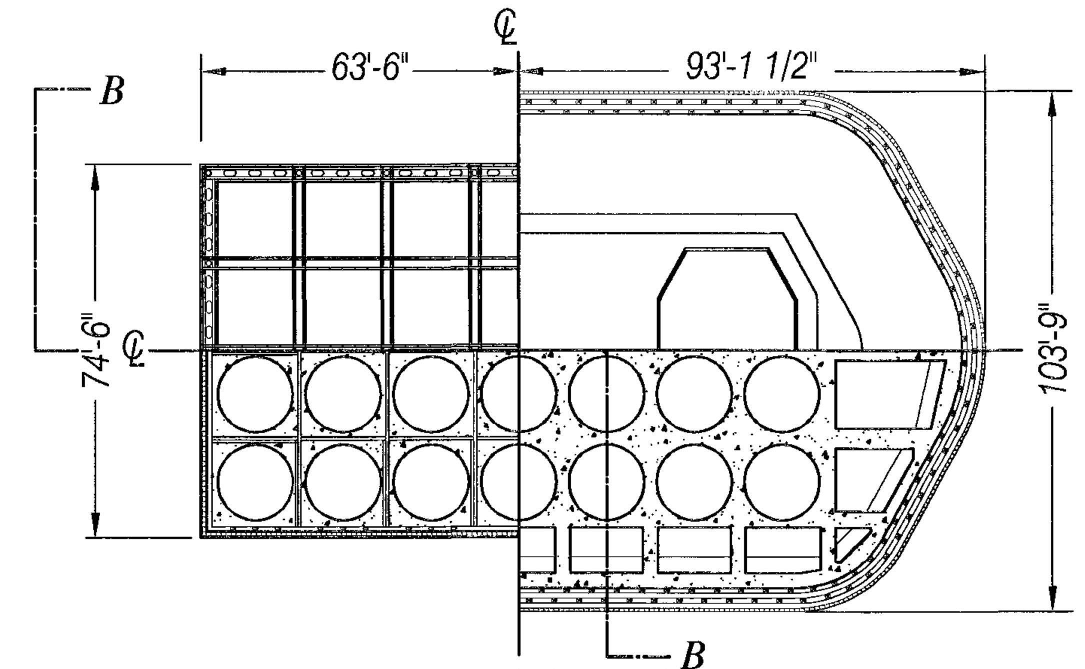
NAME AND LOCATION OF STRUCTURE
SAN FRANCISCO OAKLAND BAY BRIDGE (OAKLAND-SAN FRANCISCO BAY BRIDGE)
SPANNING THE SAN FRANCISCO BAY SAN FRANCISCO CITY AND COUNTY CALIFORNIA

HISTORIC AMERICAN ENGINEERING RECORD
CA-32

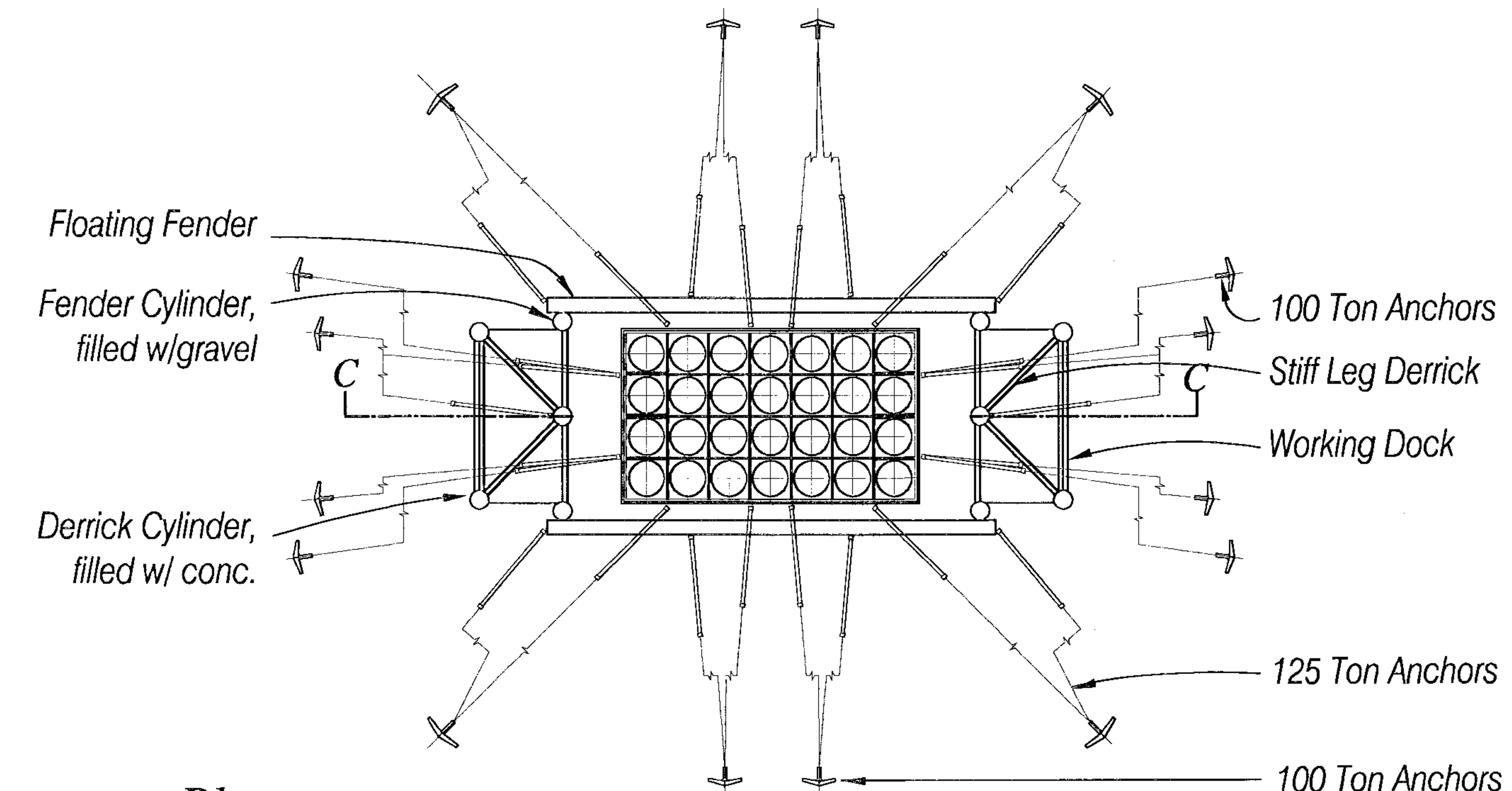
TRIM LINE



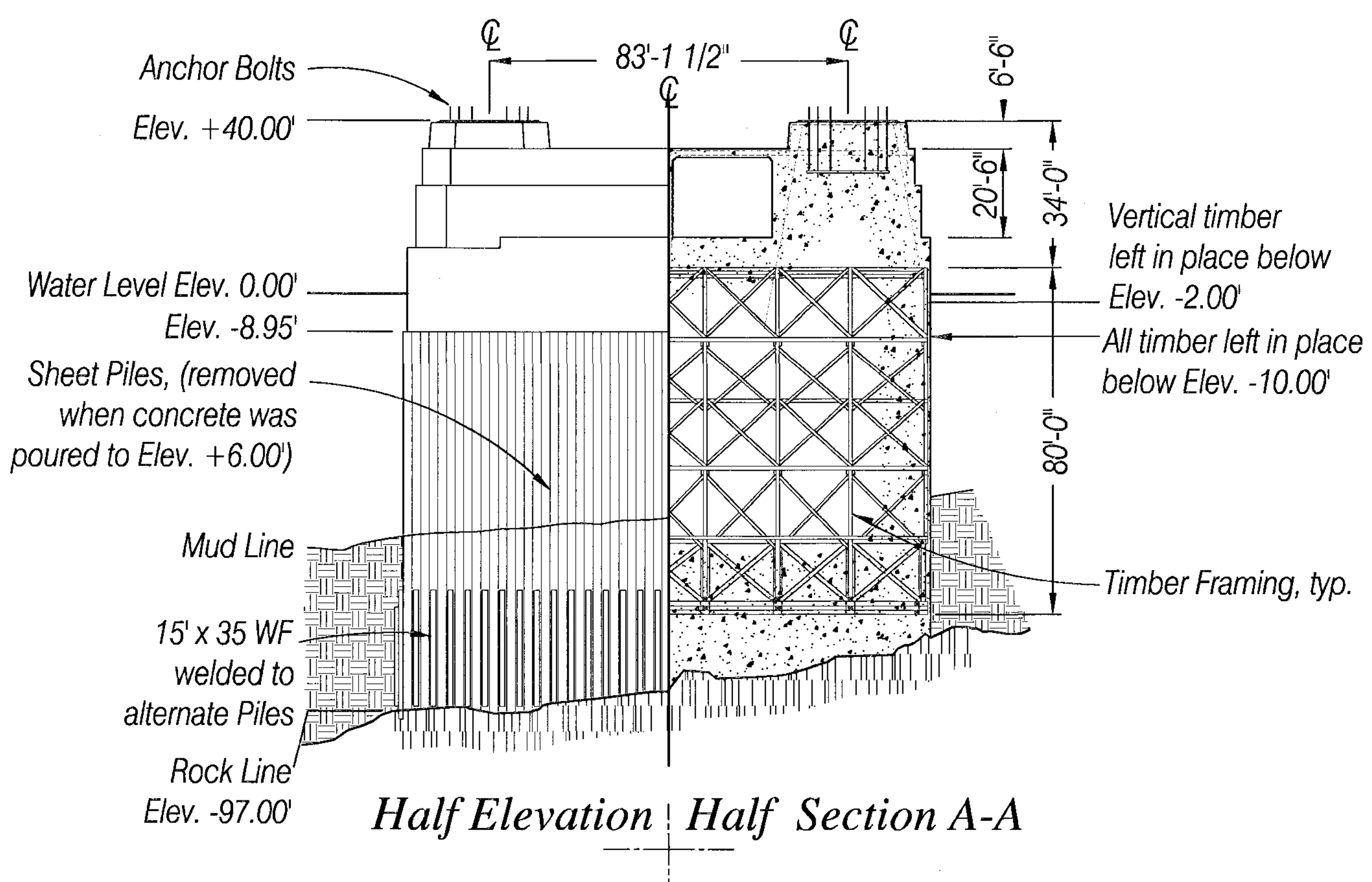
1/4 Plan @ Elev. -70.0' | 1/4 Plan @ Elev. -10'
1/4 Plan @ Elev. -55.0' | 1/4 Plan @ Elev. 40.0'



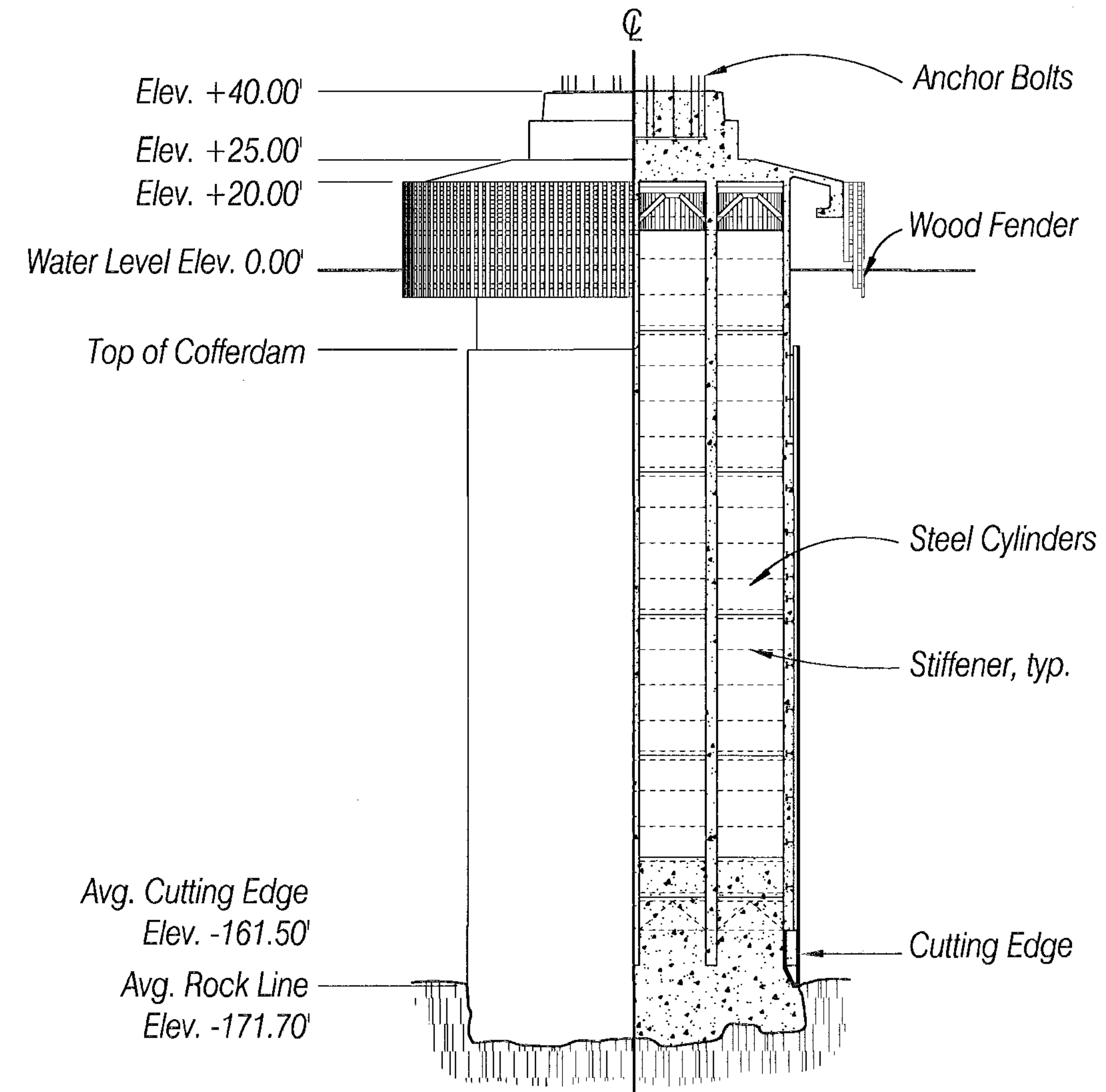
1/4 Plan @ Cutting Edge | 1/4 Plan @ Elev. 40.0'
1/4 Plan @ Caisson | 1/4 Plan @ Fender



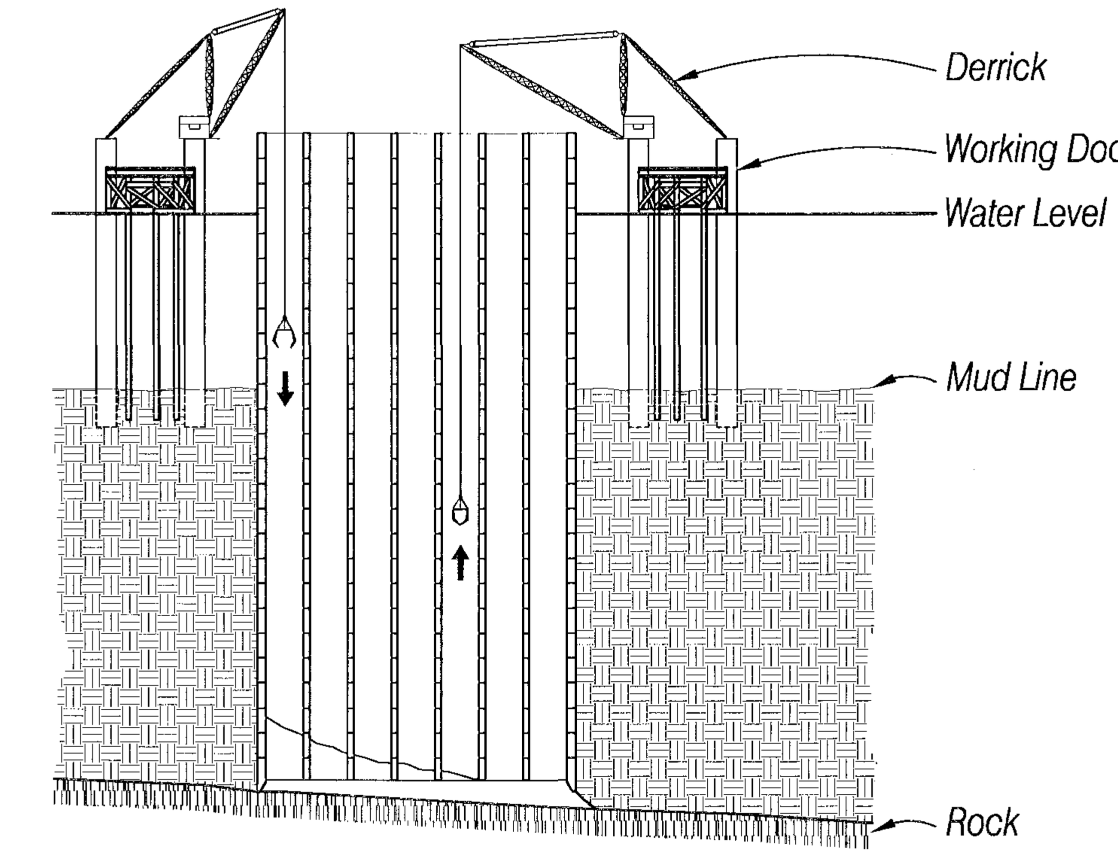
Plan



Half Elevation | Half Section A-A



Half Elevation | Half Section B-B



Reaching Rock: Section C-C

Construction Operations (W3 Shown)

SCALE IN FEET 0 30 60
SCALE IN METERS 0 6 12 18

Sheet Pile Cofferdam (W2 Shown)

SCALE IN FEET 0 15 30
SCALE IN METERS 0 3 6 9

The steel structure of the suspension bridge begins at the San Francisco Anchorage and extends to the Yerba Buena Island anchorage. Piers numbered W-1 through W-6 support the span. There are two intermediate piers, A and B, between the San Francisco anchorage and pier W-1. Foundations for piers W-1 and W-2 are reinforced concrete, cast in place in open cofferdams constructed of sheet piling. Pier W-1 is built on reclaimed tidelands and extends 60 ft. below the water's surface. Pier W-2 is the first pier in the water and was constructed using the outer end of a steamship dock as a working platform. Bedrock was found 88 1/2 ft. to 105 ft. below the water, which was shallow enough to permit the use of sheet piling. A timber frame (56 ft. by 112 ft.) was floated into place and sunk by weighting it down. The sheet piling was driven around the timber frame to the depth of bedrock. Sand and mud were excavated to expose the bedrock. The bedrock surface was then cleaned and inspected by divers. The first portion of concrete was placed in the submerged cofferdam with dump buckets. When a seal was formed at the bottom, water was pumped out and the remainder of the concrete was pured in the dry cofferdam. Most of the wood timbers were left in place, and the sheet piling was removed.

Cellular Caisson (W6 Shown)

SCALE IN FEET 0 15 30
SCALE IN METERS 0 3 6 9

A new method of construction called the "Domed-Cylinder Method" was developed for piers W-3, W-4, W-5, & W-6 to penetrate the extreme depths of mud and composite materials and to reach bedrock, which ranged from 107 ft. to 224 ft. below the water line. Pier W-4 was the largest pier in the world, extending from 217 ft. below the water to 281 ft. above the water. Construction of the pier began with a rectangular caisson, using steel spacers and stiffeners. To accommodate extreme water pressure, a timber shell was constructed with 10" X 12" vertical timbers faced with 4" X 12" diagonal timbers, sealed with oakum, and cemented. A steel grid with a sharp cutting edge at its base was constructed at the bottom of the caisson for support and to cut through the bay mud. The interior of the caisson contained a grid of steel cylinders 15 ft. in diameter and spaced 17.5 ft. center to center. Airtight hemispherical domes were welded to the top of the cylinders to permit the caissons to be floated out and anchored into position. Working docks were then built on each end of pier W-3 and on each side of pier W-4. At piers W-5 and W-6, work was done from derrick barges. Heavy timber floating fenders were built to protect the caissons and to block wave activity. Sinking the caisson was accomplished by pouring concrete into the spaces around the sealed cylinders. The air pressure within the cylinders, which controlled the rate of descent, ranged from 17 psi to 42 psi depending on the depth below the water. To lower the caisson, air was released from a few cylinders at a time, the domes were removed, new sections were added and the cylinder was repressurized. After the caisson settled into the mud, the domes were removed and the underlying mud and composite material was removed with clamshell buckets. This continued until the caisson reached bedrock. Divers were sent down to inspect and clean the bedrock surface. Then, concrete was lowered to the bottom using dump buckets to form a 34 ft. deep mat of concrete. The three cylinders in each corner of the caisson were filled with concrete, and the remaining ones were filled with water. The tops were sealed with a concrete slab in which anchorages for the steel towers were embedded.

WEST SPAN FOUNDATION SYSTEMS

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JOSEPH ATALLA, 1999 TEXT BY: DAN PETERSON, AIA

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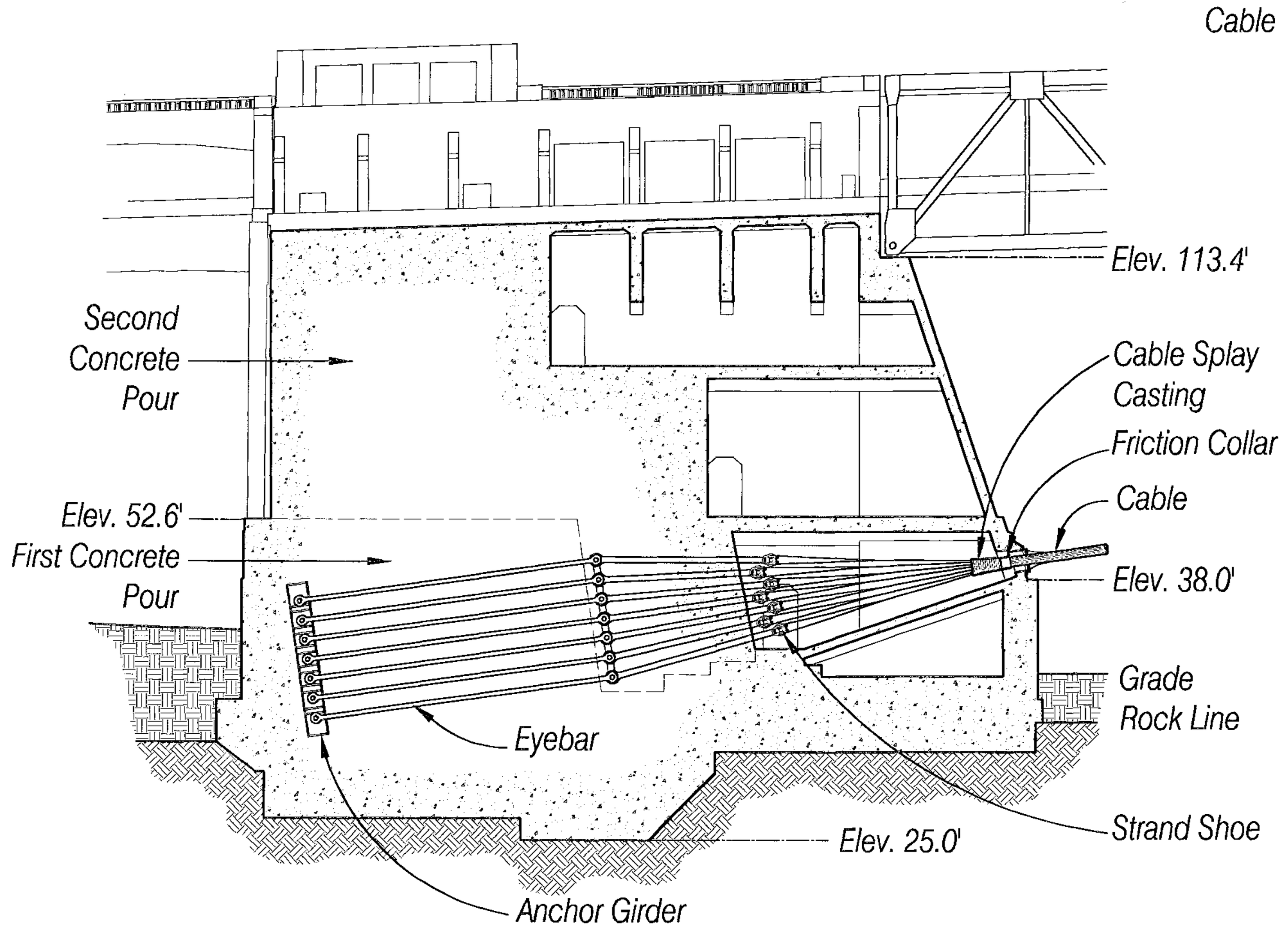
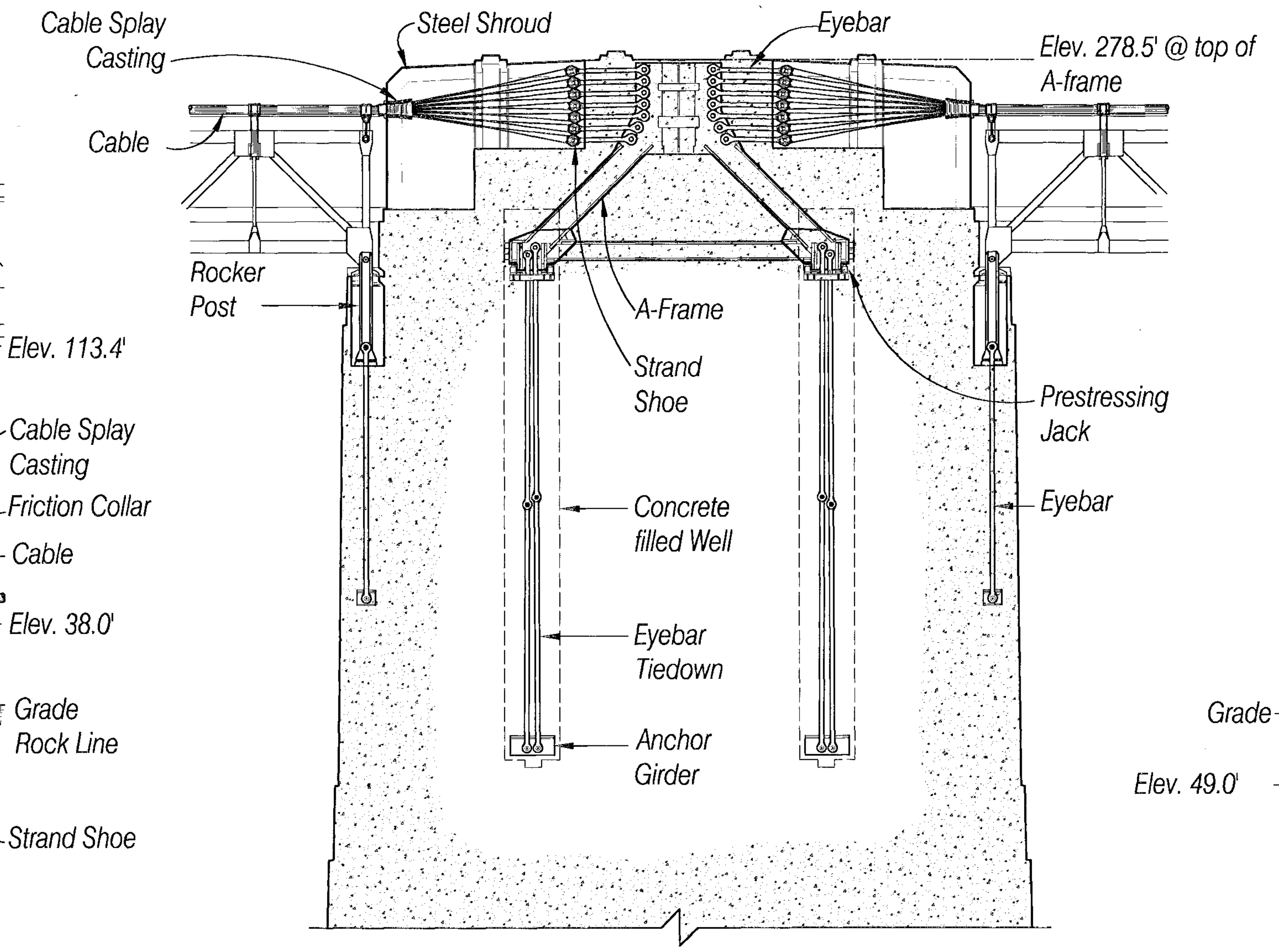
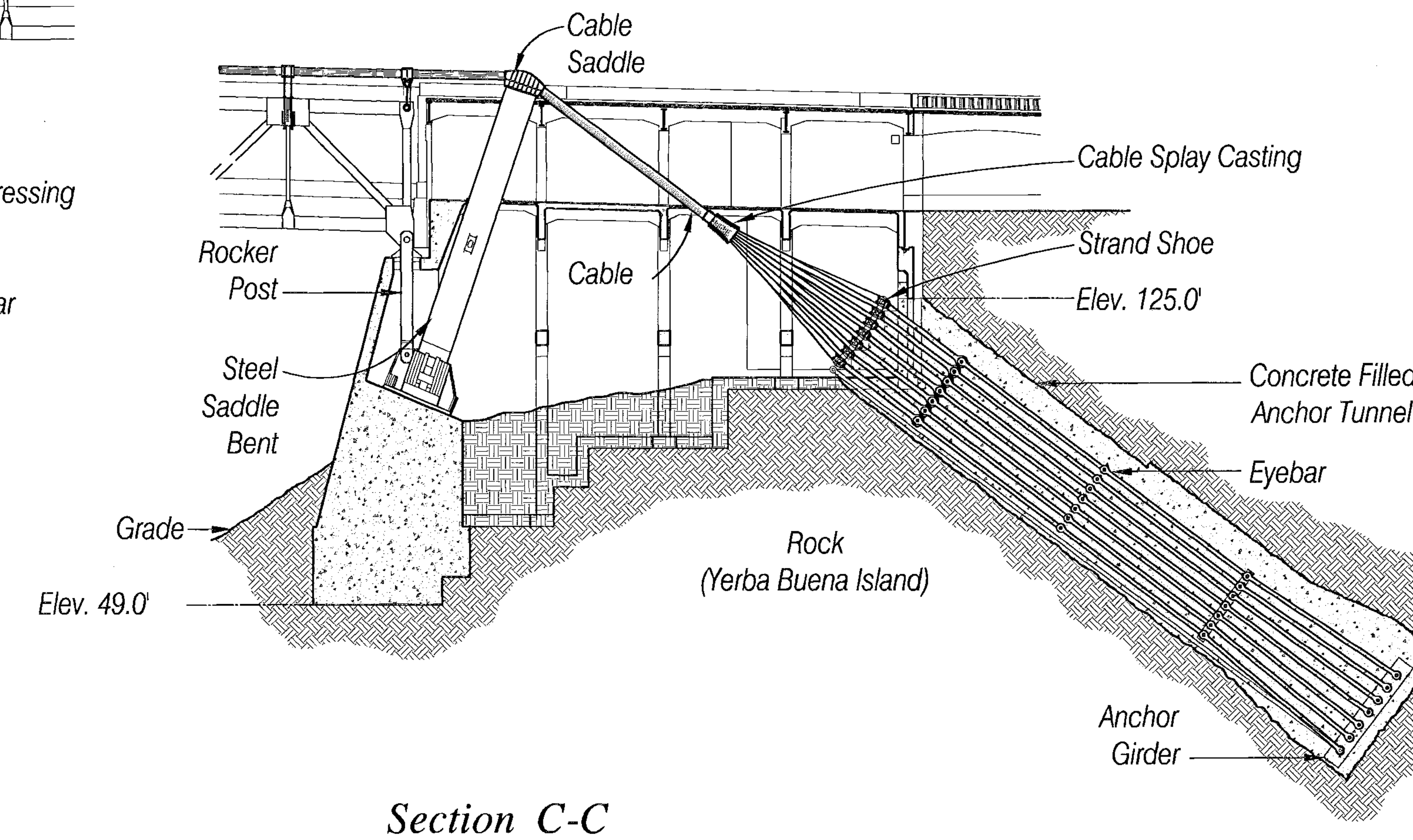
TRIM LINE



Section A-A



Section B-B



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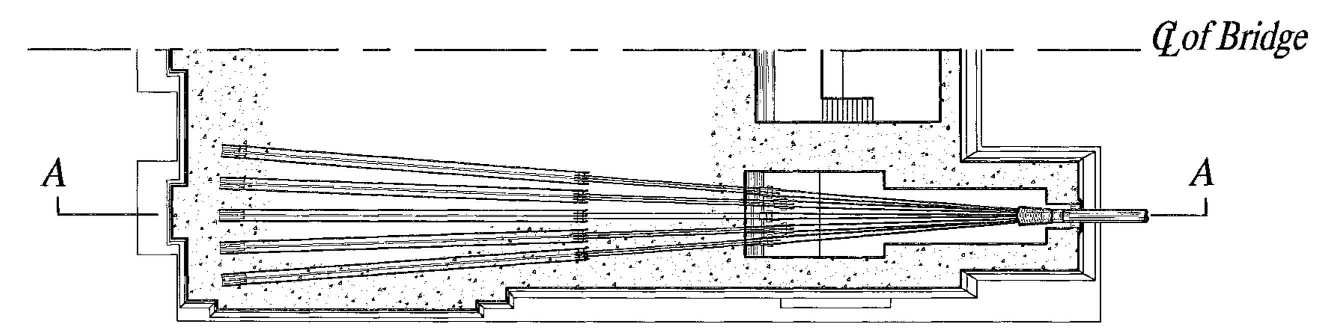

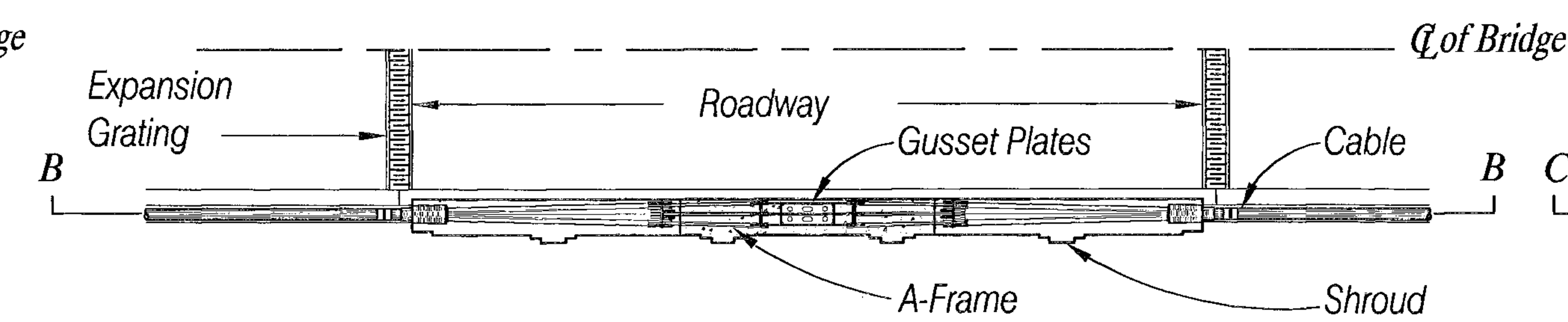

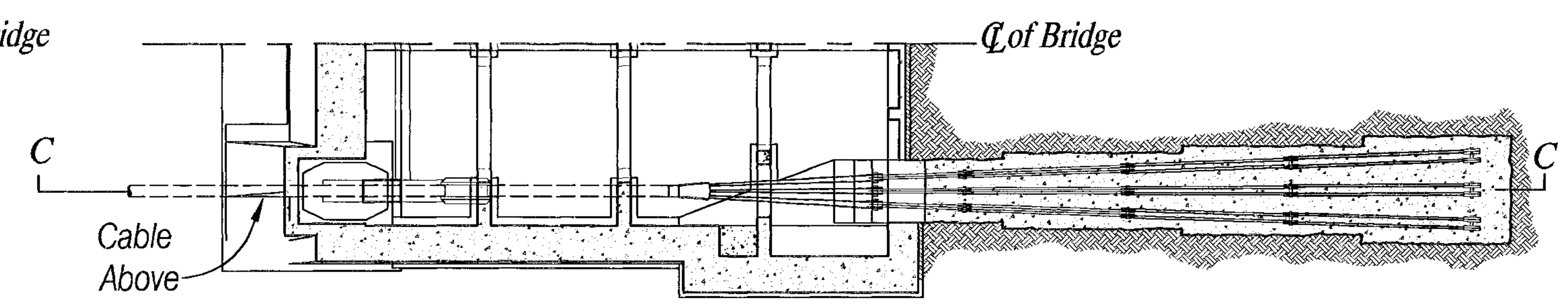

Half Plan @ Elev. 46.0'

San Francisco Anchorage

SCALE IN FEET 0 15 30
SCALE IN METERS 0 3 6 9

The San Francisco anchorage is a large concrete structure that serves as both a pier and an anchorage. It is a gravity type anchoring system that relies on the weight of the structure and the foundation system to anchor the main cable. The structure is 184.5 ft. long by 108 ft wide and rises 148 ft. above the neighboring streets. The top of the structure contains a double deck road system which connects the San Francisco viaduct and the continuous spans that approach the main suspension bridge. The anchorage is located 890 ft. from the end of the suspension bridge where the soil conditions are better. This position also allowed the cable to enter the structure at a lower level to minimize the overturning caused by the cable pull. The anchoring system consists of strand shoes at the cable ends, pinned to two sets of eyebars chained together, and an anchorage girder at the opposite end. The structure contains approximately 68,000 cubic yards of concrete and 1200 tons of steel. It was poured in three major steps. The first pour was up to a point that would cover the steel anchorage girder, which consisted of 700 tons of steel. The anchorage girder and the first set of eyebar chains (60 total) were then encased. To permit movement of the second set of eyebar chains, (45 bars total), they were not enclosed in concrete until after the cable spinning was complete. The last step was to complete the remainder of the concrete structure.

Half Plan @ Elev. 278.5'

Center Anchorage

SCALE IN FEET 0 15 30
SCALE IN METERS 0 3 6 9

The center anchorage was the most inventive anchoring system of its time, connecting two back-to-back suspension bridges. The concrete portion of the anchorage extends up to the lower road deck (235 ft. above the water) and consists of two longitudinal concrete side walls with an average thickness of 13 ft. and end walls averaging 5 ft. in thickness. The top is concrete and forms the road bed of the lower deck. The side walls contain a well for the installation of the 135 ft. "A" frame eyebar tie downs. These wells were ultimately filled with concrete. The interior of the structure is braced with a series of concrete struts. The structure above the lower deck is steel which encloses the anchorage system and provides the structure for the upper deck. The anchorage system consists of two "A" frames (one for each side of the bridge) which sit on top of the concrete pier. A set of 12 eyebars set in concrete are used to anchor the two lower legs of each "A" frame. Attached to the top of the each "A" frame is a series of eyebars (38 each direction) which anchor the cable strands. The "A" frame and eyebars are encased in concrete from the lower deck up. At the upper joint of the "A" frame are three gussets, capable of resisting 40,000,000 pounds, that help form the splice between the east and west suspension cables. At this point the dead load cable pull of 30,000,000 pounds is balanced. Unbalanced live loads (resulting from the car, train and truck traffic) cause an uplift on one stem of the "A" frame, which is resisted by the eyebars extending into the pier.

Half Plan @ Elev. 125.0'

Yerba Buena Anchorage

SCALE IN FEET 0 15 30
SCALE IN METERS 0 3 6 9

The Yerba Buena anchorage uses the rock island to anchor the cables. The cables bend over saddle bents and loop around the strand shoes at the back of the structure. The strand shoes are pinned to eyebar chains that extend into a 170 ft. tunnel that widens toward the bottom and angles down at 37 degrees. The eyebar chain consists of four bars in each chain. The tunnel was filled with concrete, leaving the upper most chain exposed to permit movement during the cable spinning process. Once the cable was completed, the last chain was encased in concrete leaving only the eyebar ends and strand shoes exposed. The cable bent is 84 ft. high and is tilted 19 degrees. The cable bent was allowed to move during construction of the cable to equalize the forces on the cable as it was fully loaded. This structure is at the end of the eastern suspension span and the beginning of the double deck roads to the Yerba Buena Island tunnel.

Key Plan - West Bay Crossing

NOT TO SCALE

ANCHORAGES

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JOSEPH ATALLA, 1999   TEXT BY: DAN PETERSON, AIA

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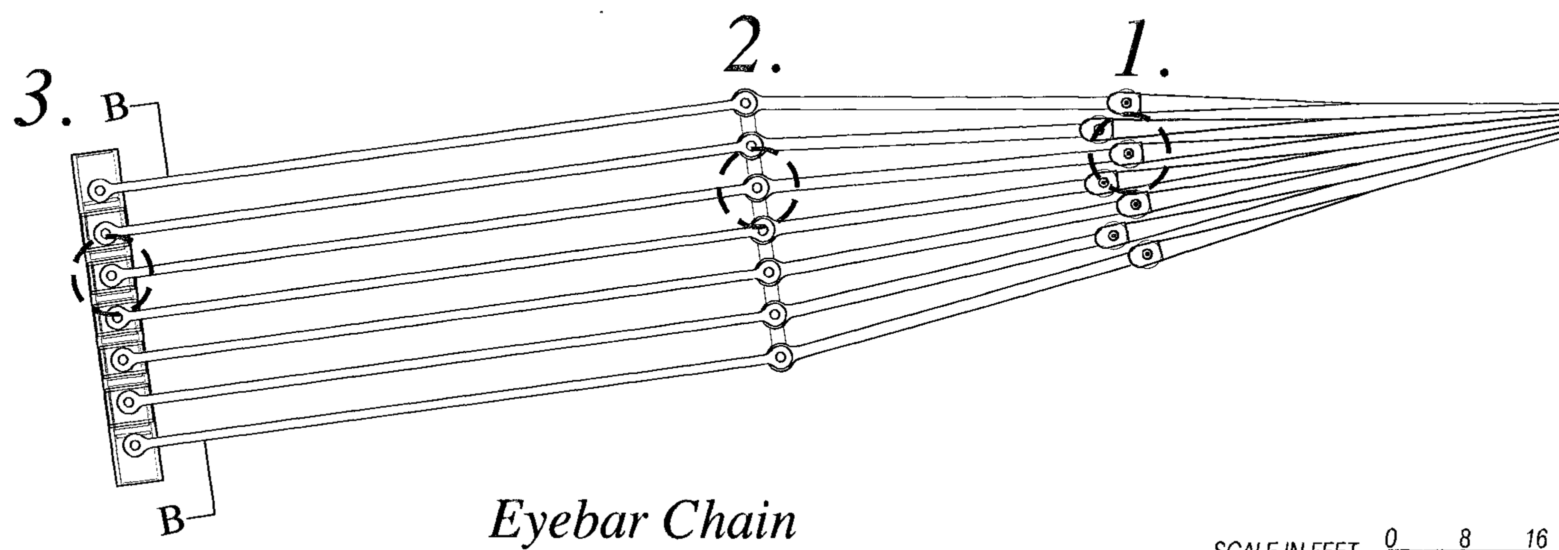
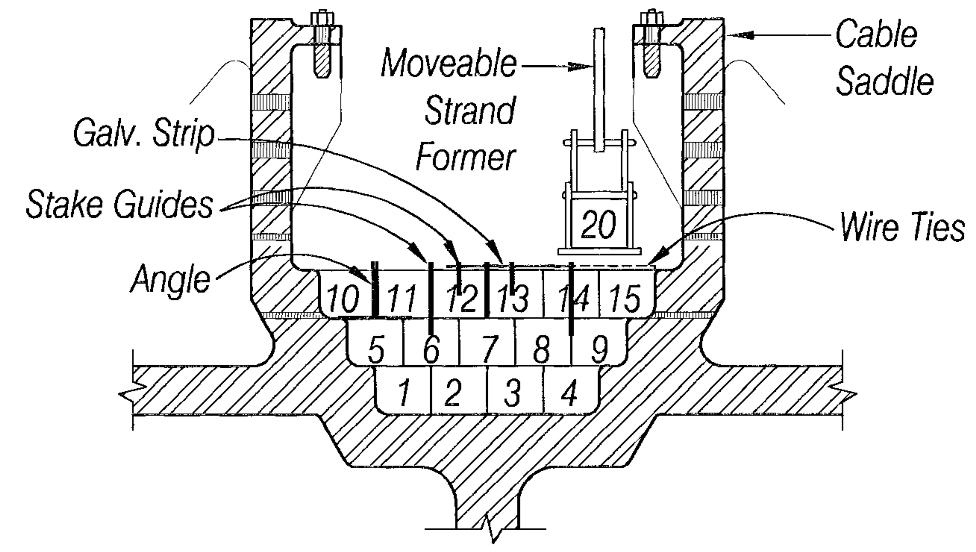
TRIM LINE



Eyebar Chain

San Francisco Anchorage

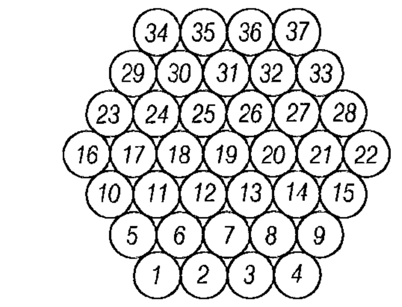
SCALE IN FEET 0 8 16
SCALE IN METERS 0 1.6 3.2 4.8



Strand Setup Section A-A

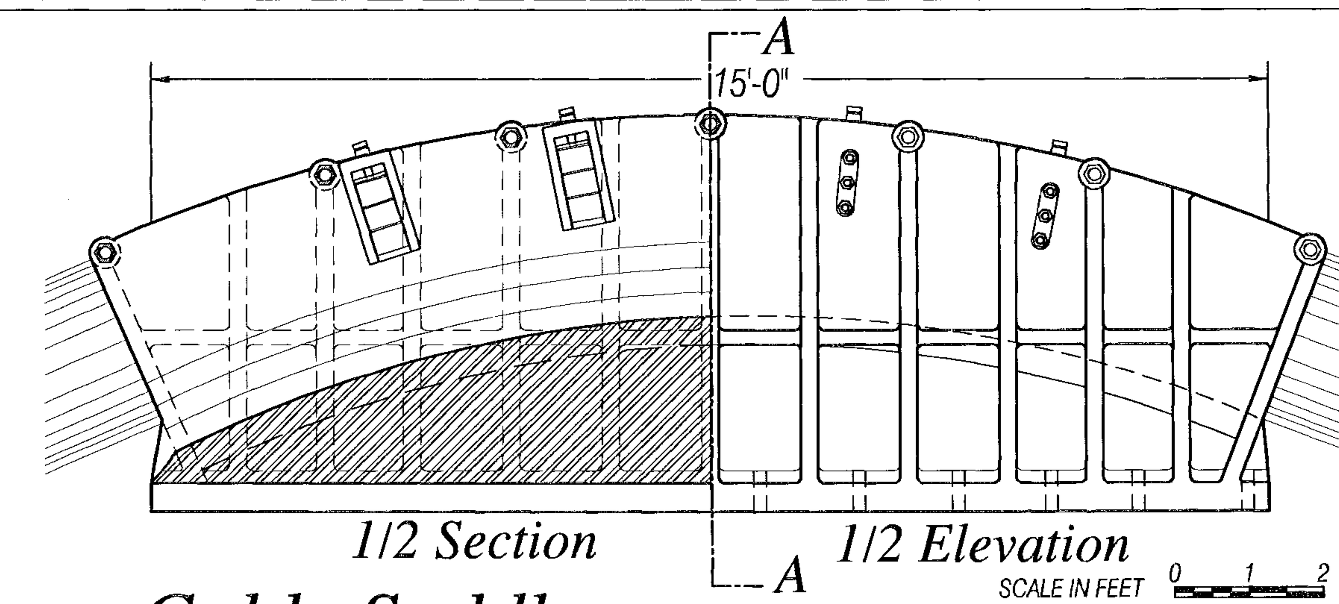
(Set up #4 Illustrated)

SCALE IN FEET 0 .5 1
SCALE IN METERS 0 .1 .2 .3



Strand Pattern in Main Cable

(NOT TO SCALE)

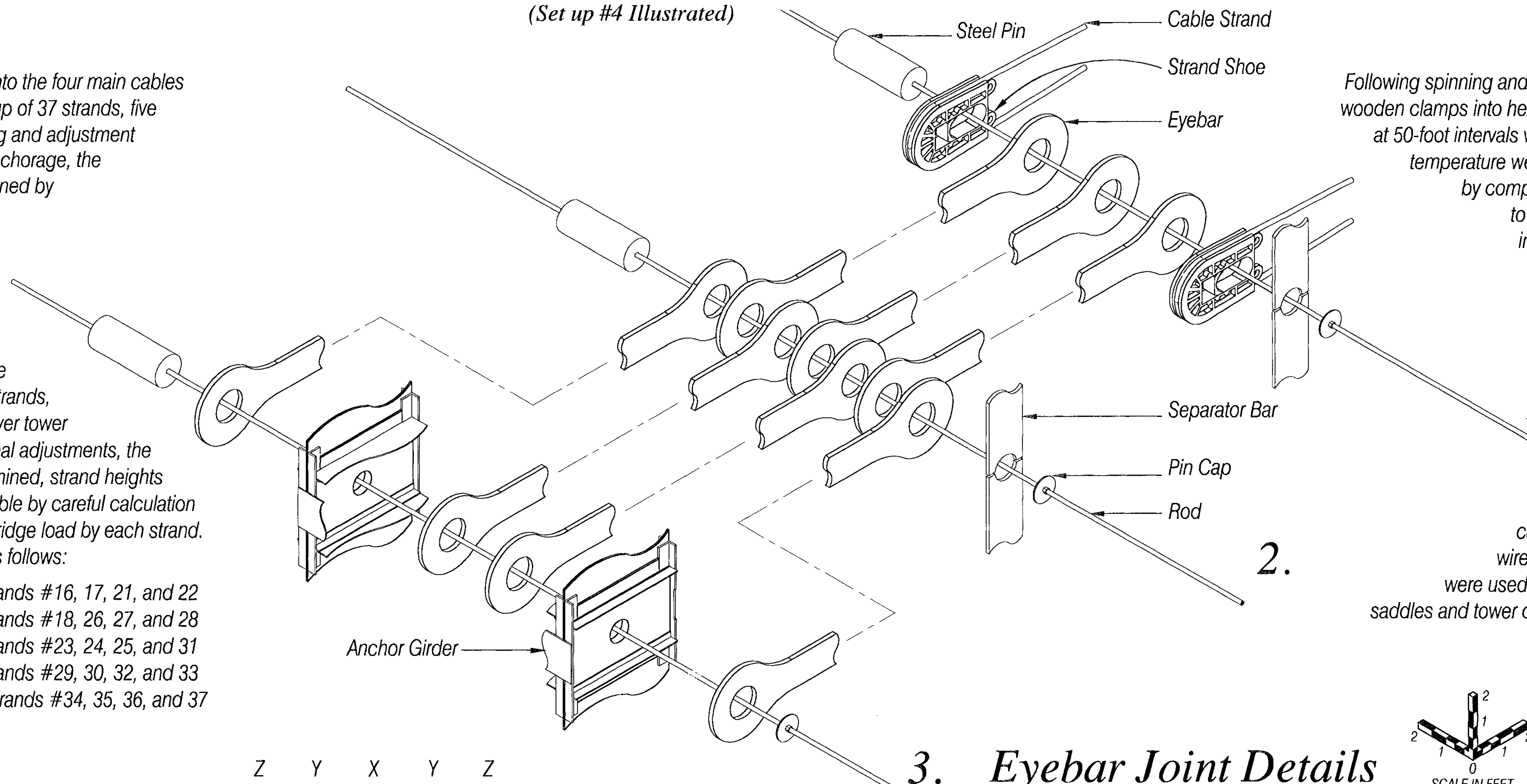


Cable Saddle

SCALE IN FEET 0 1 2
SCALE IN METERS 0 .2 .4 .6

In all, 19,112 tons or 70,649 miles of cable wire were spun into the four main cables of the West Bay suspension spans. Each cable was made up of 37 strands, five inches in diameter, constituting the largest diameter spinning and adjustment units yet attempted. Where the main cables entered each anchorage, the 37 strands are splayed and regrouped into patterns, determined by the size and configuration of each anchorage. The grouped strands wrap around cast steel shoes, which are joined by a steel pin to high tensile strength eyebars, which are anchored to girders within each anchorage. In order to effect "in place spinning" and permit adjustment of the individual wires, strand shoes were shimmed back so that strands at mid-span were one to one and one-half feet above final position in the cable. After spinning the set-up of four strands, each strand had to be adjusted by longitudinal movement over tower saddles and the removal of shims at the anchorages. On final adjustments, the temperatures of strand units and of main cables were determined, strand heights noted at mid-span, and strands set to final position in the cable by careful calculation and measurement thus assuring equal participation of the bridge load by each strand. 10 set ups were required to spin the 37 strands which are as follows:

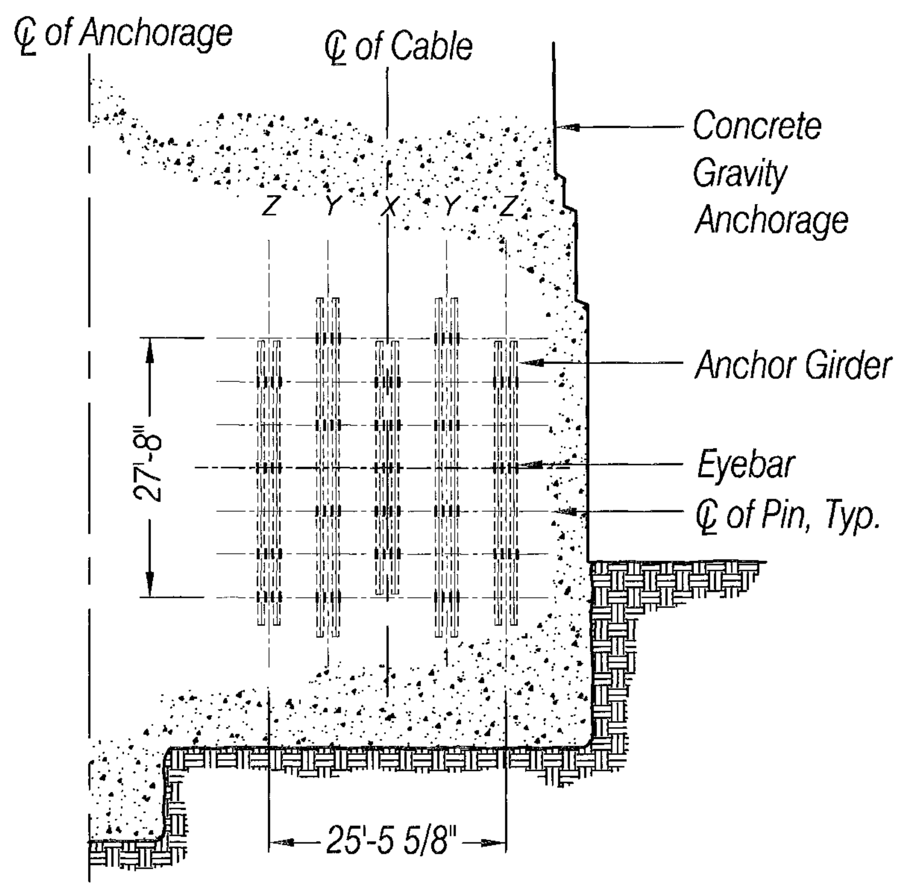
- Set up #1- Strands #1, 2, 3 and 4
- Set up #2- Strands #5, 6, 8, and 9
- Set up#3- Strands #7, 12, 14, and 15
- Set up #4- Strands #10, 11, 13, and 20
- Set up #5- Strands #19
- Set up #6- Strands #16, 17, 21, and 22
- Set up #7- Strands #18, 26, 27, and 28
- Set up #8- Strands #23, 24, 25, and 31
- Set up #9- Strands #29, 30, 32, and 33
- Set up #10- Strands #34, 35, 36, and 37



Following spinning and adjustment, the 37 strands forming each main cable were banded by wooden clamps into hexagonal sections with top and bottom faces horizontal. These clamps at 50-foot intervals were set from midnight to six a.m., when distortions of the cables from temperature were at a minimum. Special machines then completed the final forming by compacting the strands into a circular cable 28.84 inches in diameter, held to shape by temporary wire seizings every three feet. Voids between the individual wires were reduced to 19.6 per cent by the compaction. The wood cable clamps were removed as they were approached by the compacting machine. Cable bands of cast steel, over which suspenders were to be looped, were then clamped onto the compacted cable and secured against slipping along the cable by two-inch diameter high-tensile bolts. One band was required at each point of support for the suspended structure, approximately every 30 feet measured along the bridge deck. The main cable wrapping protects the most vital elements in a suspension bridge. A special wrapping machine wound the serving wire under tension in continuous coils around the cable, at the same time crowing the coils together to form an unbroken wire metal seal between cable bands. After completion of spinning, jacks were used to center the saddle and top of the tower. Contact surfaces between saddles and tower caps were paraffined before erection to facilitate the jacking operation.

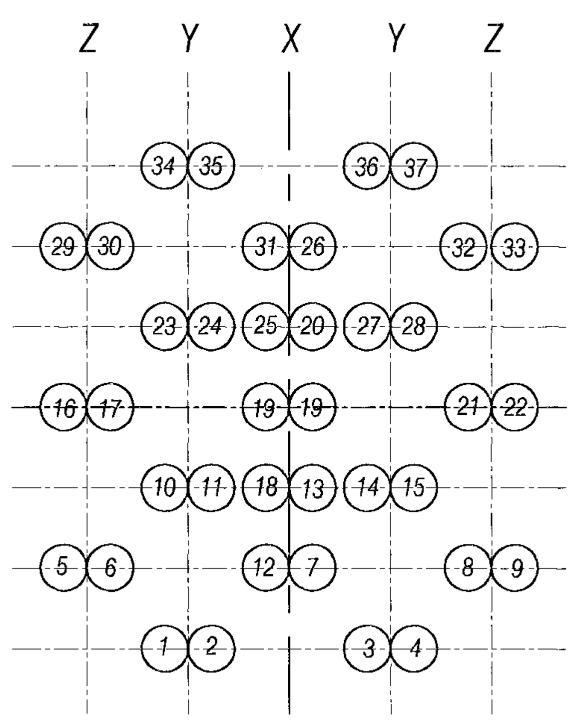
Eyebar Joint Details

SCALE IN FEET 2 1 0 1 2
SCALE IN METERS .6 .3 0 .3 .6

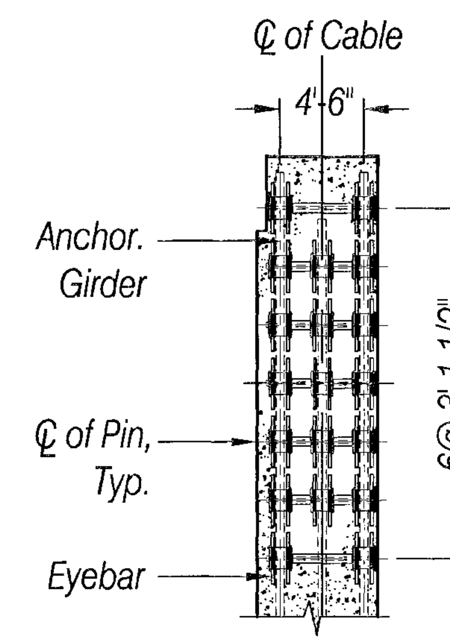


San Francisco Anchorage Section B-B

SCALE IN FEET 0 8 16
SCALE IN METERS 0 1.6 3.2 4.8

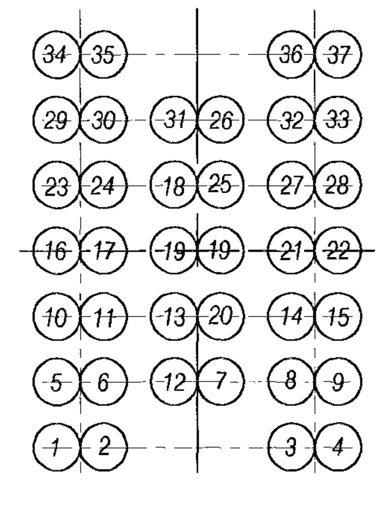


Strand Pattern @ S.F. Anchorage (NOT TO SCALE)



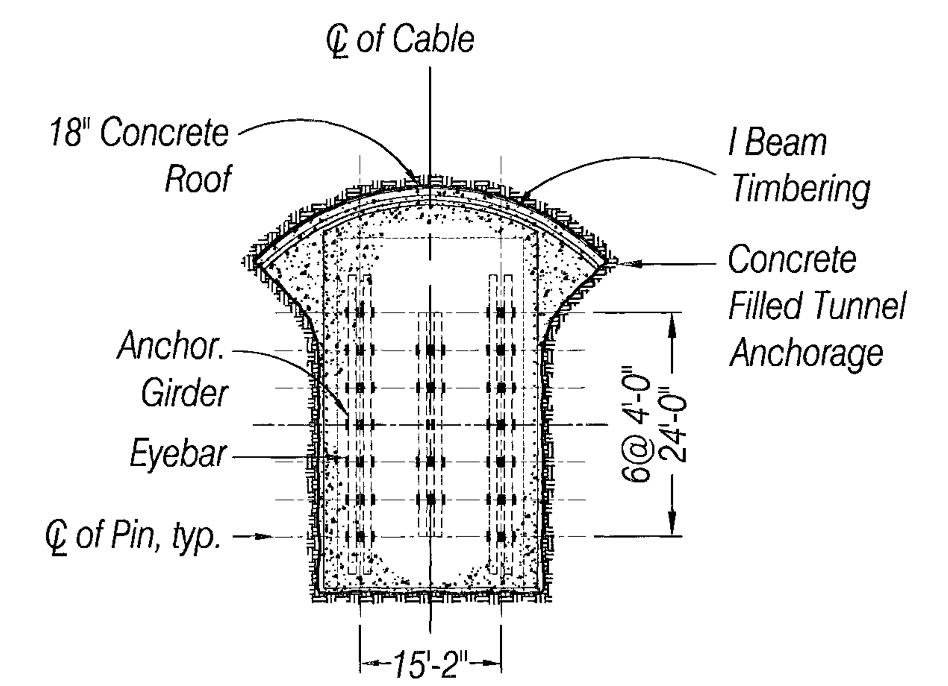
Center Anchorage Section

SCALE IN FEET 0 4 8
SCALE IN METERS 0 .8 1.6 2.4



Strand Pattern @ Center & Yerba Buena Anchorages

(NOT TO SCALE)



Yerba Buena Anchorage Section

SCALE IN FEET 0 8 16
SCALE IN METERS 0 1.6 3.2 4.8

ANCHORAGE & CABLING DETAILS

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/IZUMI MASUDA, 1999 TEXT BY: DAN PETERSON, AIA
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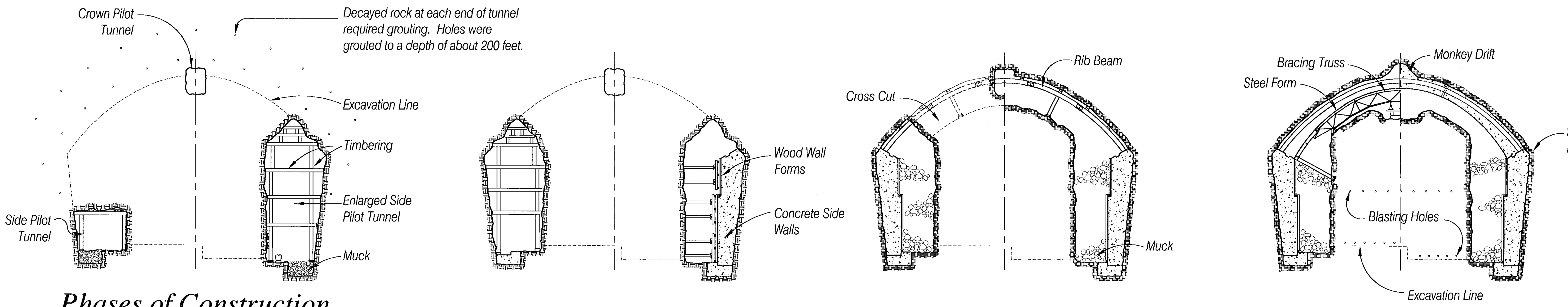


Phases of Construction

Phase I (Pilot Bores)

A pilot tunnel 8' high X 6' wide, at the crown of the arch, was started July 26, 1934 and was completed Oct. 6, 1934. Material was hand mucked into a 1 yd. car on track laid as work progressed. No timbering of this tunnel was required. Next, pilot tunnels 14' wide by 12' high were constructed at each side. Timbering in these tunnels was of 10" X 10" and 12" X 12" posts and caps, and 12" X 12" and 8" X 8" lagging. Spacing of the timbering varied from 5' to 8' centers, depending on ground conditions. The side pilot tunnels were enlarged vertically to the excavation line of the main tunnel roof by stoping and drifting. Muck was caught on a floor of 6" X 6" timbers and trapped through to cars on the track below. The slope was timbered with square sets of 8" X 8" timbers, and 2" X 8" lagging as required. Spacing of sets was 4' to 8'.

Phase II (Sidewalls Poured)

Wall forms were of 5 ply 4' X 8' plywood panels with 2" X 6" studs @ 14" centers, on 6" X 6" Wales @ 4' centers stulled and wedged against the core. Pipe line for delivery of concrete was supported on the tunnel timber above the pour and raised for succeeding lifts of the pour. Pipes were discharged into hoppers with elephant trunks placed in these forms at about 12' intervals.

Phase III (Cross Cuts)

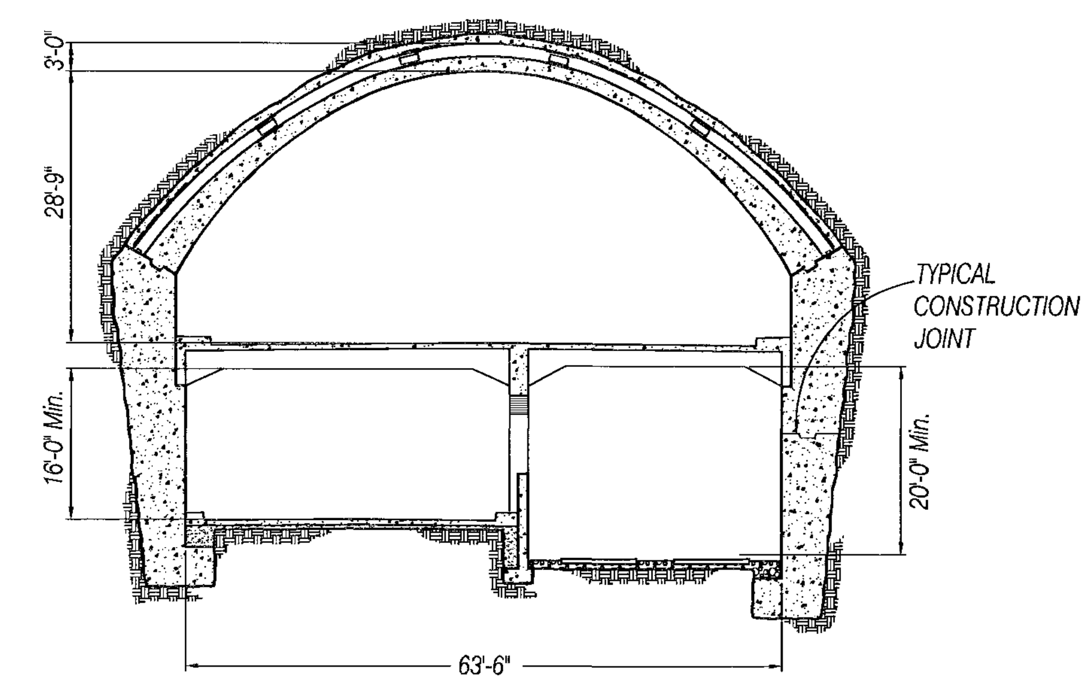
Six cross cuts were made along the periphery of the arch at intervals varying from 20' to 135'. As space was cleared, rib beams were hoisted to place in sections, bolted together, stulled against the core and wedged against the ceiling. Part of the muck was dropped in the space along the side walls and part was loaded in a small car, pushed to the portals and dropped in the approach cuts.

Phase IV (Concrete Ceiling)

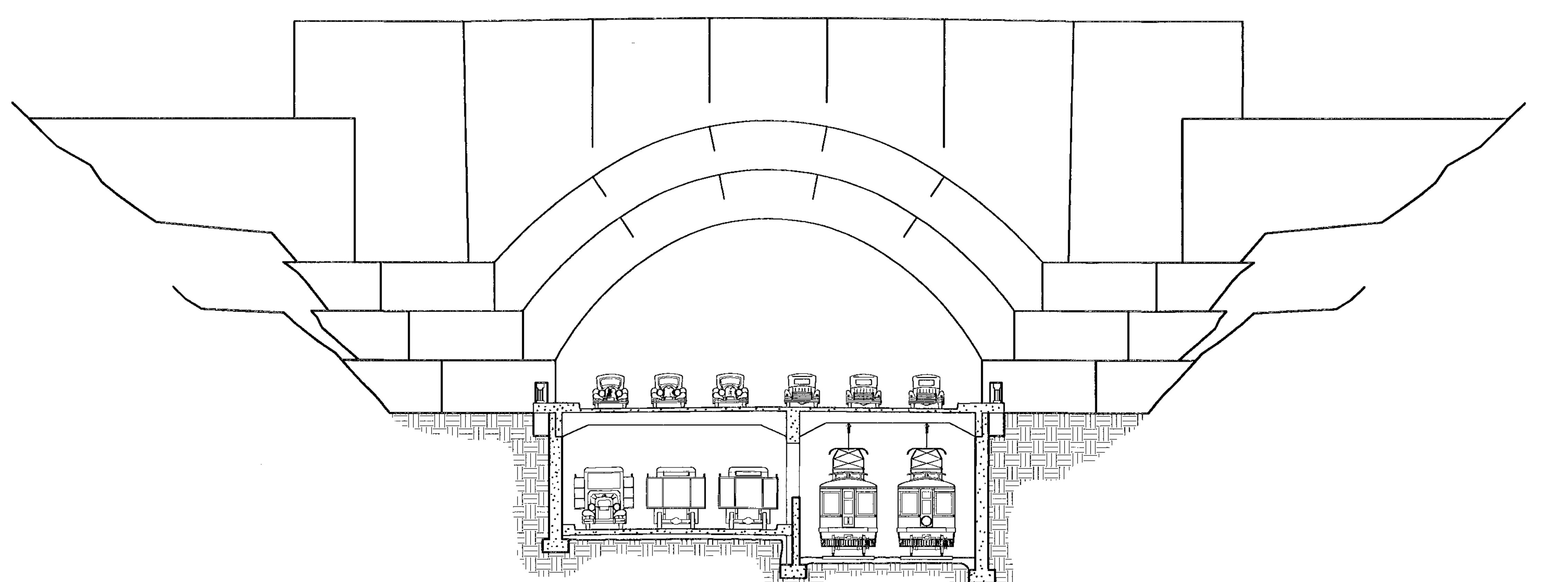
Two steel forms, each extending from spring line to spring line and 20' long, were moved to place on a 4-wheeled car traveling on track laid in the core along the centerline of the tunnel. After setting to line and grade, the forms were securely stulled, bulkheads were erected and reinforcing steel was placed. Concrete for the west form was delivered through a pipe line laid in the monkey drift above the arch. Concrete pipe for the east form was delivered in pipe laid alongside of the track on top of the core and turned up into the monkey drift near the form. Pours were made alternately in the west and the east forms progressing towards the middle. Concrete was discharged into small hoppers fitted with two-way gates opening into sectional chutes leading down to the spring lines. As pouring progressed chute sections were removed. At the crown, workmen and equipment were withdrawn into the monkey drift making it possible to pour tight against the rock and about one foot above the H-beam ribs. After the arch was poured, the monkey drift was filled with concrete. Three lines of grout holes were drilled through the arch to rock above and the roof was grouted at 40 psi.

Phase V (Core Excavation)

The core excavation was begun after the arch had cured. Blasting holes 8' to 15' deep were sprung with 3 to 5 sticks of dynamite and then loaded with 30 to 65 sticks and fired in relays. Excavation was completed Nov. 30, 1935.



Typical Section



West Portal Elevation

SCALE IN FEET 0 8 16
SCALE IN METERS 0 1.6 3.2 4.8

YERBA BUENA TUNNEL

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/IZUMI MASUDA, 1999

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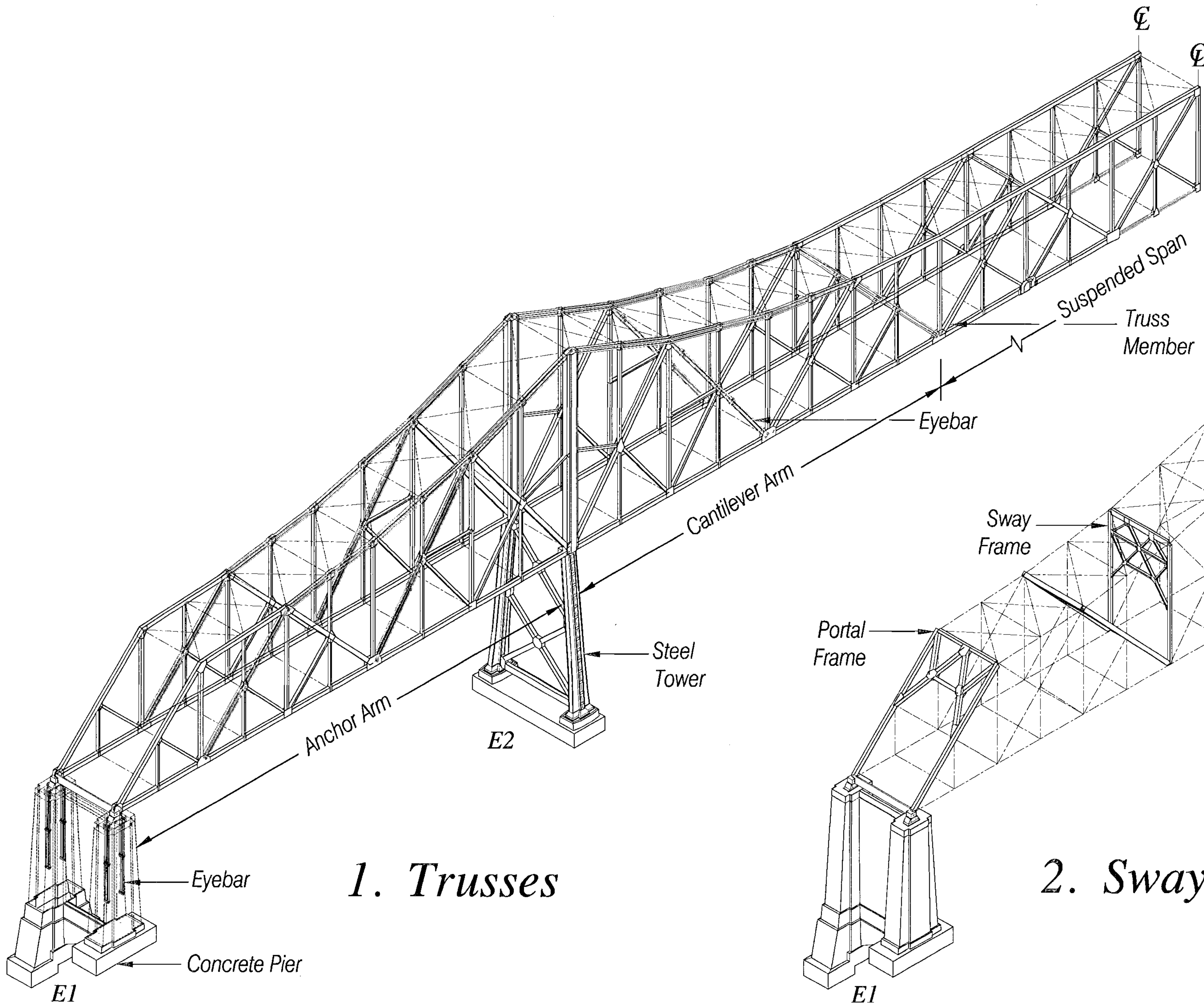
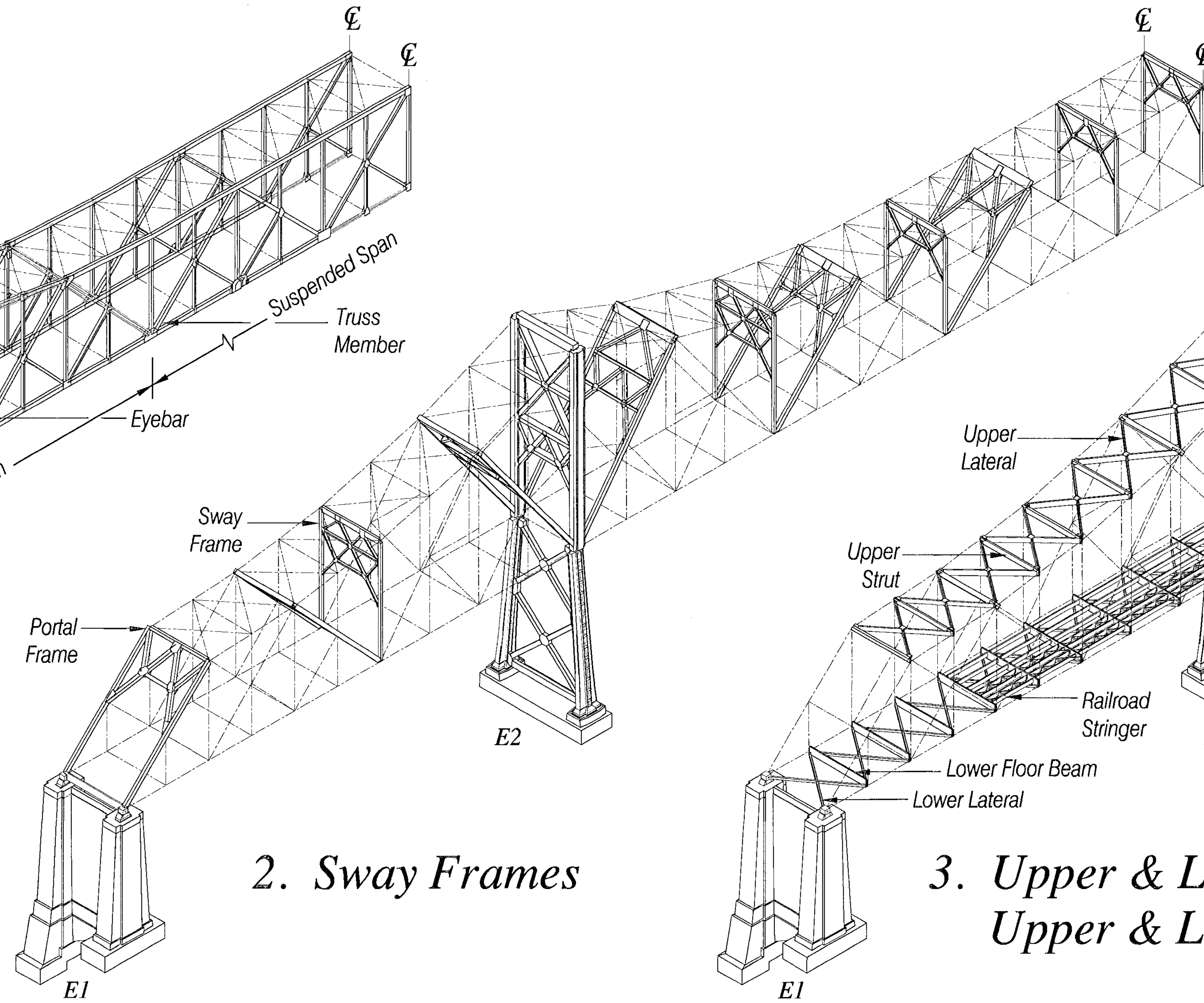
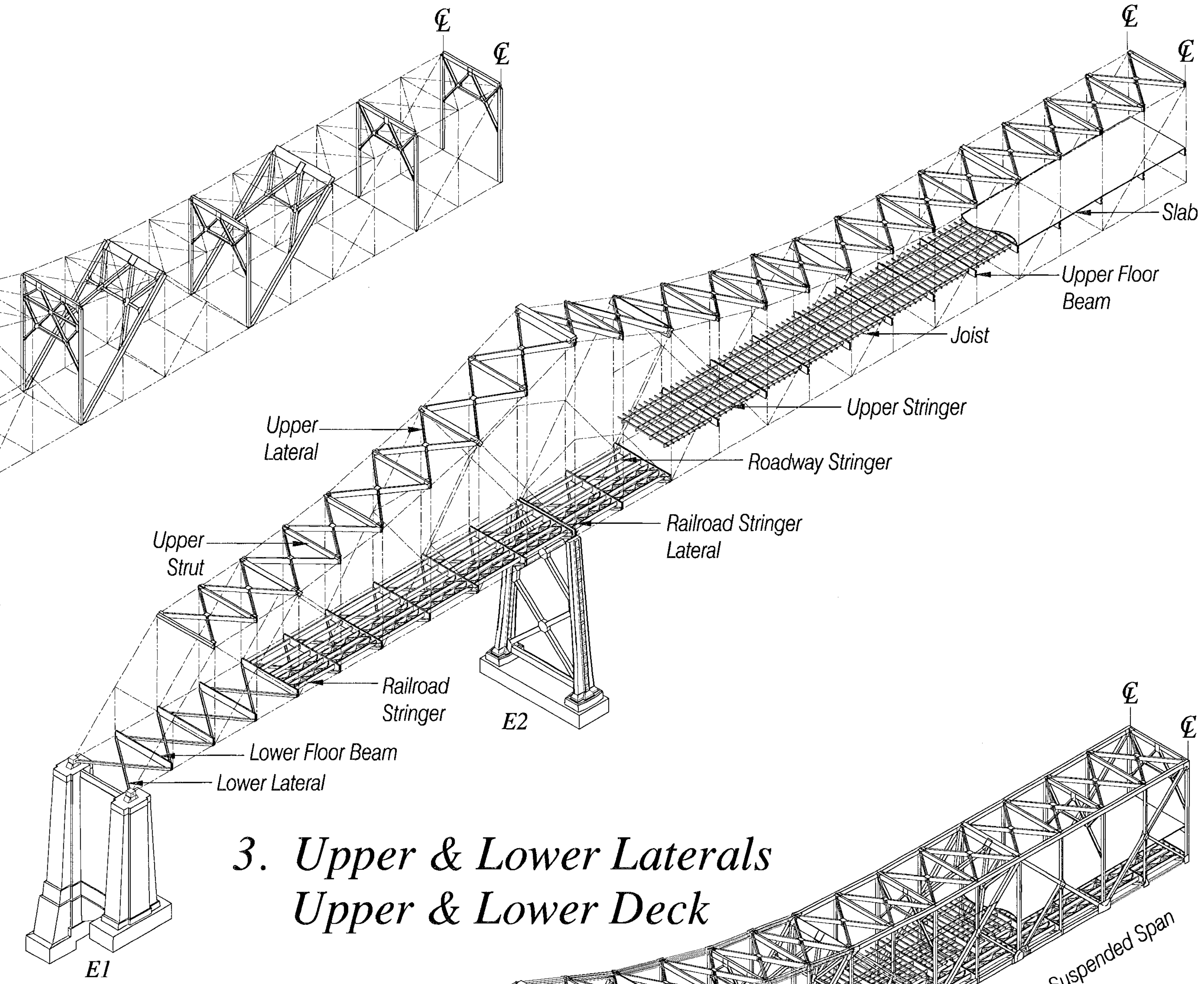


1. Trusses



2. Sway Frames



3. Upper & Lower Laterals Upper & Lower Deck

1. Trusses

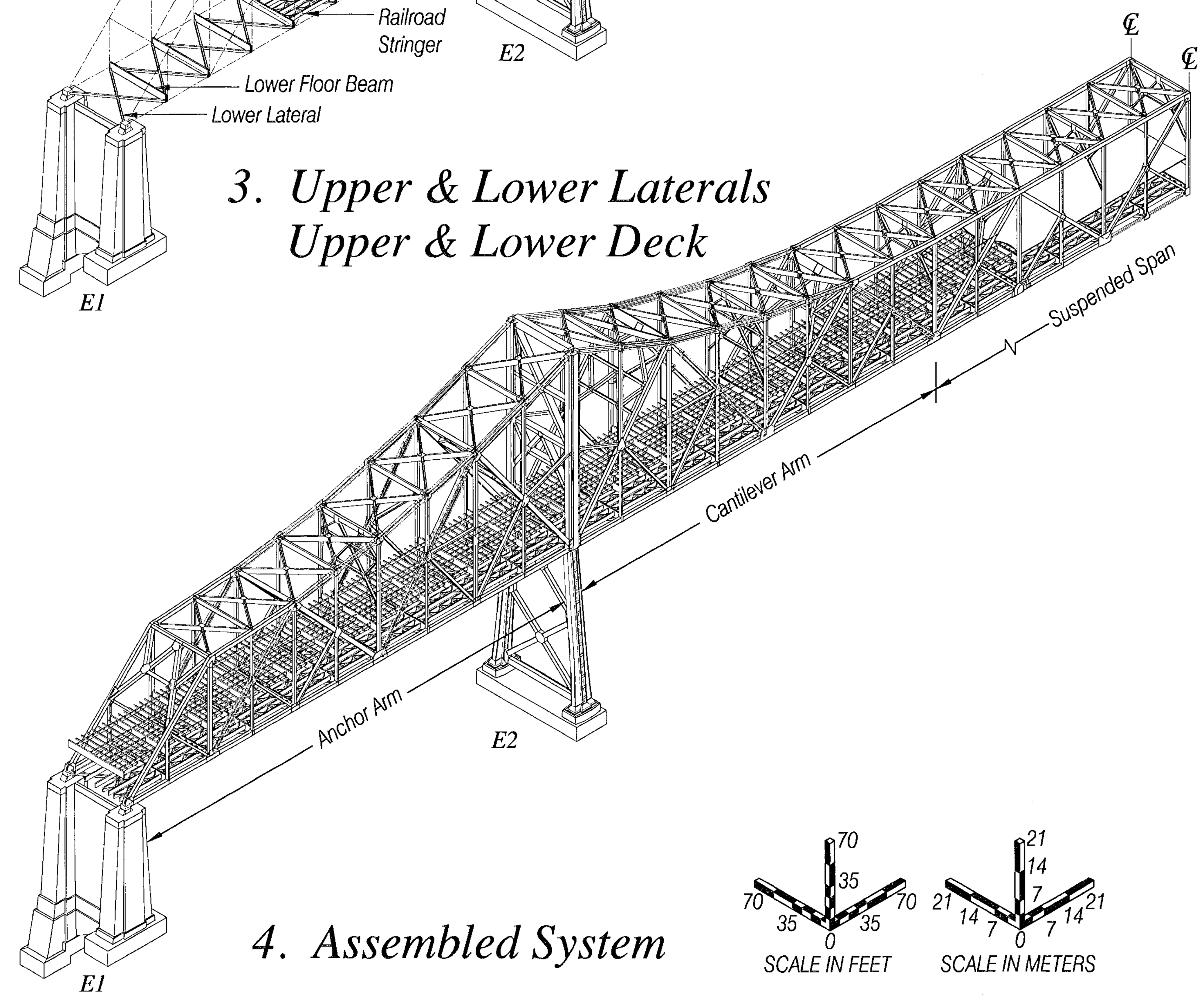
The cantilever trusses of the East Bay Crossing comprise a number of different member types designed and built to resist various forces. The connections between these members are designed to transfer forces between the members and to provide freedom from extraneous restraints that cause undesirable secondary stresses in the members. In the cantilevering portion of the trusses, three types of forces must be resisted. In the top chord of the cantilever truss, bending actions result in large tension forces. These forces are carried by multiple parallel eyebars - flat pieces of heat-treated steel with round holes in their ends. The eyebars are very efficient in resisting tension but have essentially no capacity to resist compression or bending. In the bottom chord of the cantilever truss, bending actions result in large compression forces. These forces are carried by steel plates, built up into members with box cross-sections made up of angles, plates, and flat bar lacing riveted together which can resist the required compression forces without buckling. The diagonal members in the sides of the trusses carry shear forces. Diagonal eyebars are in tension while diagonal box sections are in compression. Tower E1 anchors the truss with concrete-embedded eyebars, which resist the uplift force generated by the cantilever arm. Tower E2 is in compression. The suspended span is a Warren type box truss suspended from the ends of the cantilever arms.

2. Sway Frames

The cantilever truss is stabilized against lateral forces with sway frames. These braces, located at the key panel points, span the trusses high above the upper deck traffic.

3. Upper and Lower Decks, Upper and Lower Laterals

The upper roadway is supported by a system of joists on top of stringers, which in turn are supported by floor beams. The lower deck is supported only by a system of stringers on top of floor beams. A 6 ½ in. reinforced concrete slab covers the entire upper deck and the truck traffic portion of the lower deck. The rail system is supported on wooden rail ties over pairs of stringers, stabilized by steel laterals. To stiffen the deck and provide resistance to horizontal forces, a system of lateral "X" braces span between the two side trusses, both at their top and bottom. The bracing connects at each panel: between the lower floor beams in the bottom plane, and between the upper struts in the top plane.



4. Assembled System

CANTILEVER TRUSS

(Half Unit Illustrated)

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JULIA KIM, 1999 TEXT BY: MARK KETCHUM, PH. D., P.E., DAN PETERSON, AIA

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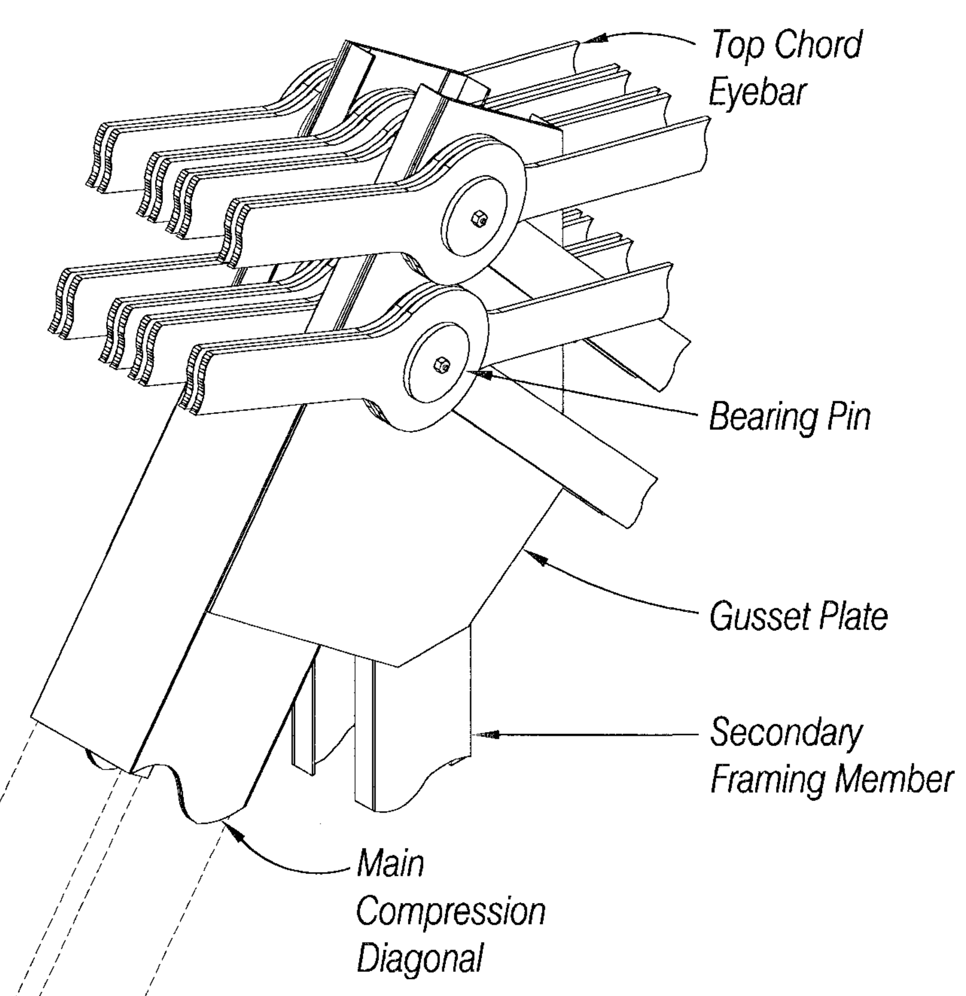
1. Panel Point L0

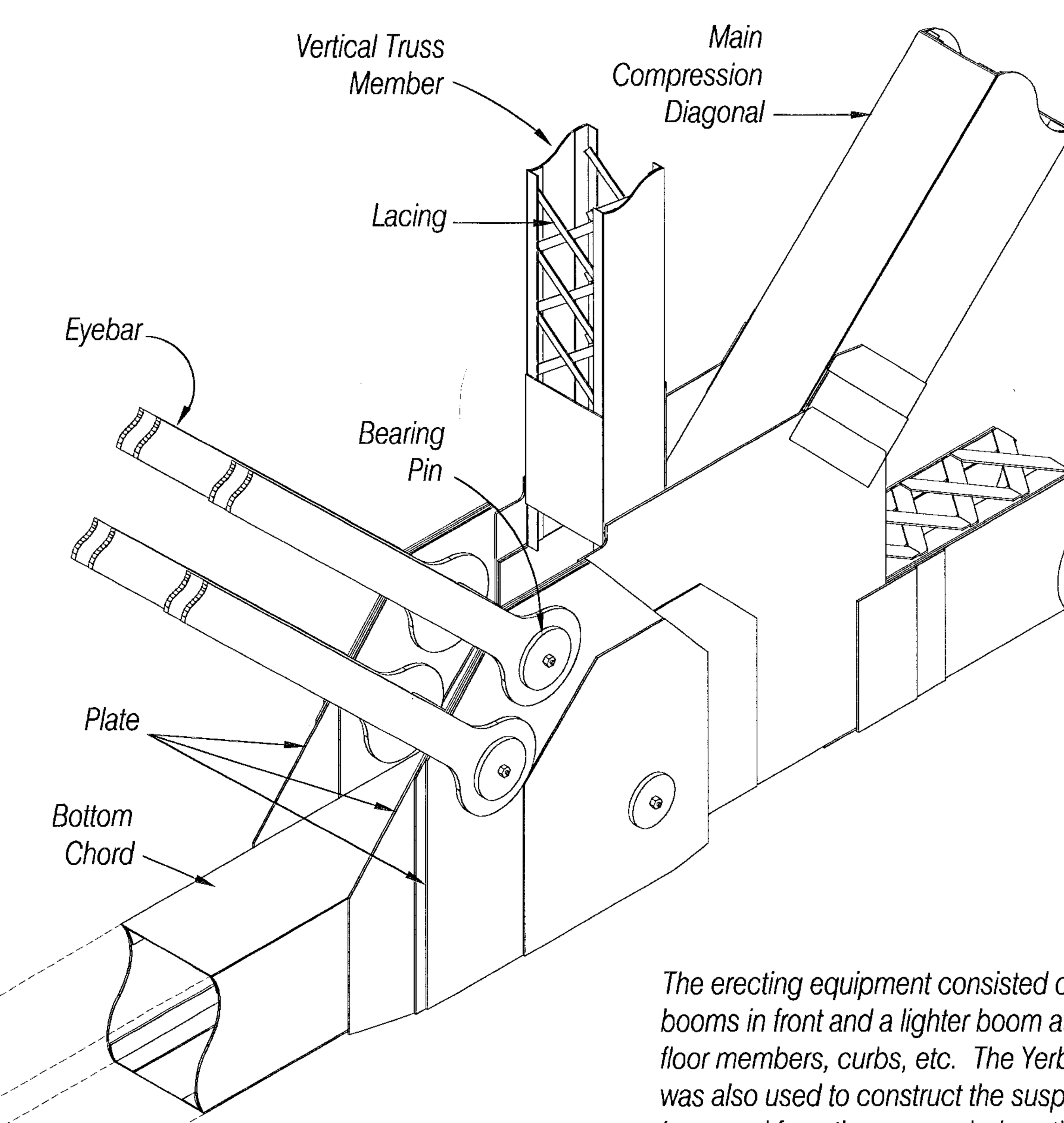
Panel point L0 is the location of the main vertical support of the cantilever span. Six major compression members converge at this panel point, so a pin-connected joint was designed and built to transfer these forces between members without unnecessary rotational restraint of the member ends, which would have caused strength-reducing secondary bending stresses. The configuration of the joint allows direct transfer of longitudinal compression forces across the joint to the complimentary member on the other side and similar transfer of all vertical loads to the pier beneath (not shown). This force transfer requires a complex cellular plate system within the joint. The five transverse pins, which connect the members to the gusset plates of the joint, allow the ends of the members to rotate independently of the joint and of each other, thereby eliminating (or at least reducing) the secondary bending stresses and allowing each member to resist compression to its full capacity.

2. Panel Point UC2

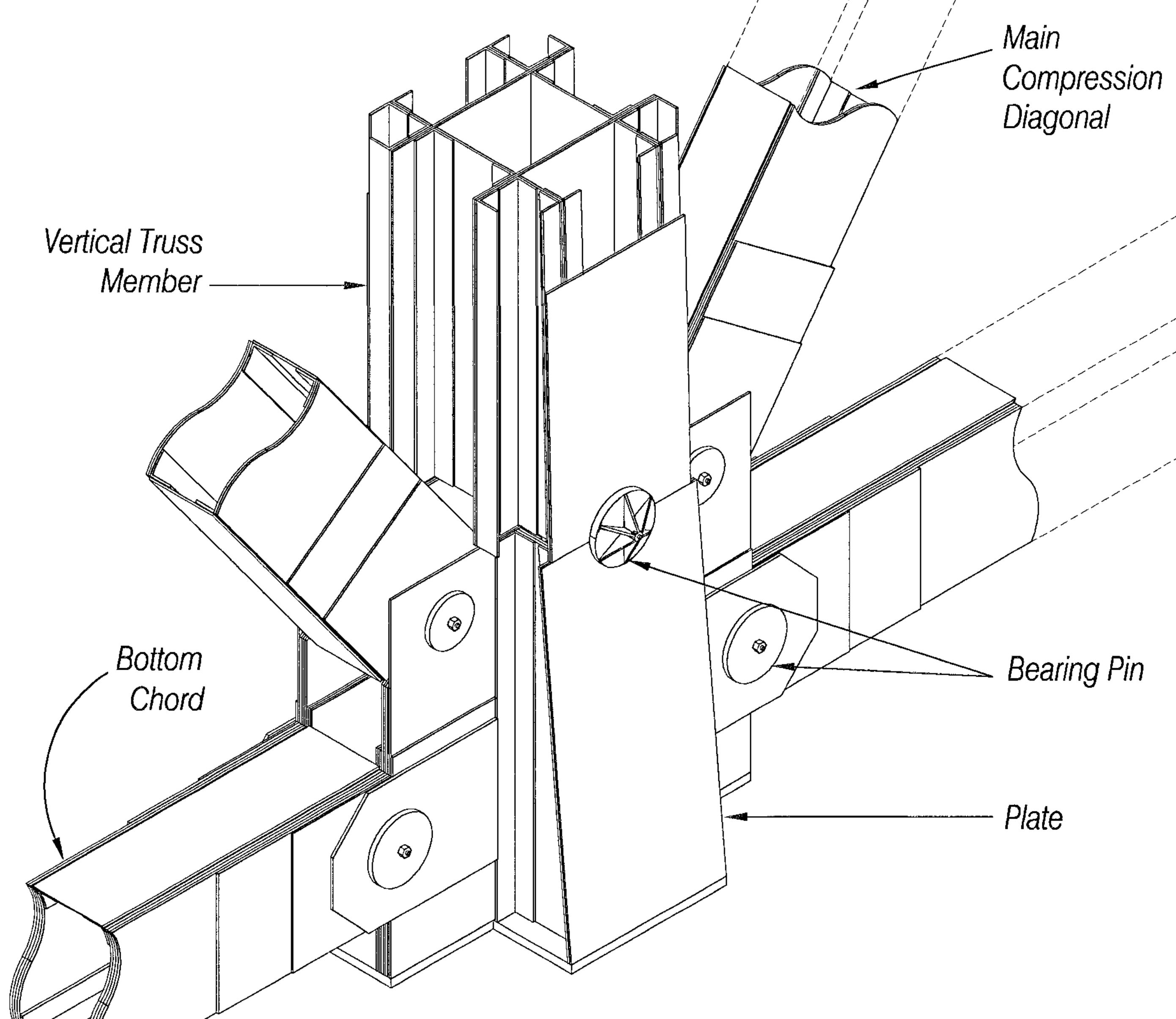
Panel point UC2 is a location where two top chord (tension) eyebar members, a diagonal box (compression) member, and a diagonal eyebar (tension) member are connected. The vertical member at this joint is a secondary framing member that does not participate significantly in the cantilever system of the bridge. The three eyebar members are connected together with bearing pins into a gusset plate. The combined forces in the three eyebar members and the vertical secondary member result in a net force aligned directly down the diagonal member. The pins that anchor the eyebars can not transfer bending; the orientation of the pins is set to minimize eccentric loads due to differential forces in the eyebars. The result is a design that efficiently transfers forces between members (through the pins and gussets) and minimizes secondary bending stresses in the diagonal compression members.



2. Panel Point UC2



3. Panel Point LS0



1. Panel Point L0

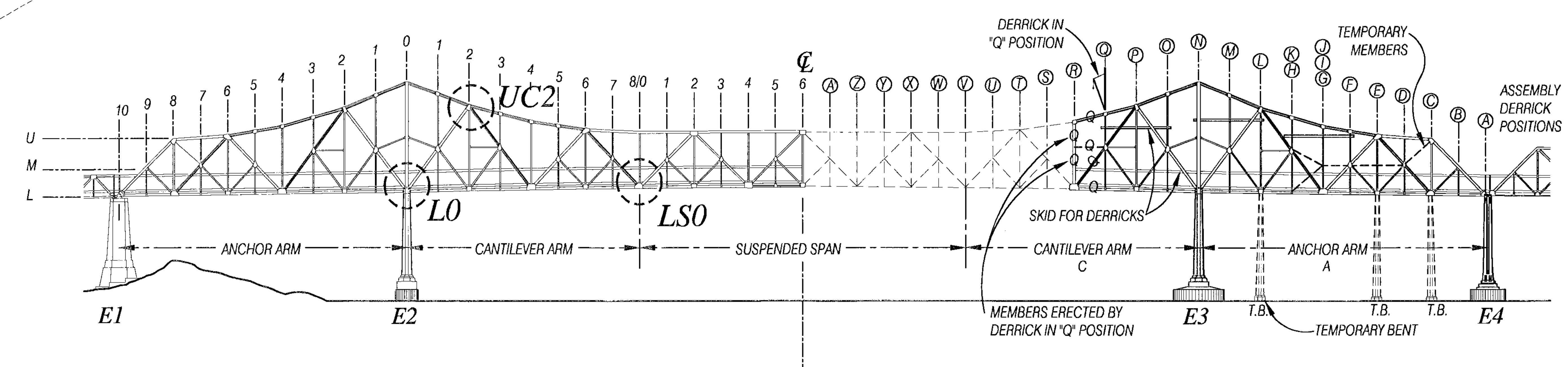
3. Panel Point LS0

Panel point LS0 marks the end of the purely cantilevered portion of the span, where the tip of the cantilever supports the suspended span that comprises the center portion of the structure. During construction, this joint was required to resist and transfer vertical and longitudinal forces. Then, upon completion of the suspended portion, the joint configuration was changed so that the suspended portion would deliver only vertical forces. The member forces are much smaller at this location than they are at L0 and UC2, so the compression members are lighter, with lacing on some faces instead of solid plates, and the tension members use fewer eyebars. In the final configuration of the joint, the pin carries all loads between the suspended and cantilever portions and allows independent rotation of the two largely independent structures. The detail also allows some free thermal expansion of the connection, with the gussets of the suspended portion nested inside those of the cantilever portion.

Construction Sequence

The construction of the cantilever truss system began at the east support (E-4) and proceeded west over three temporary bents and over tower E-3 until the cantilever arm panel point LC-7 was reached. The first temporary bent was removed after the derrick was in position "F". Construction of the western section proceeded east from tower E-1 in the same sequence as the east side, also stopping at the point LC-7. The construction continued from the west and east panel points LC-7 toward the center, cantilevering each panel section until the center of the suspended section was reached. The final connection at the center of the suspended section was assisted with hydraulic jacks located in the top chord members at the end of each cantilever arm and the end of the east anchor arm.

The erecting equipment consisted of two guy derricks mounted on one traveler, the Yerba Buena traveler with two booms in front and a lighter boom at the rear, and a jiniwink. The jiniwink was used for light work such as placing floor members, curbs, etc. The Yerba Buena Island traveler, used for constructing the continuous span trusses was also used to construct the suspended sections. The derricks moved on skids made up of the railway stringers borrowed from the suspended section and was supported by the floor beams of the upper deck. The upper deck floor beams were shored up from the lower floor deck beams to support the weight of the derrick. At panel line 4, the derricks were raised in two steps and supported on temporary floor beams attached to the vertical truss members. The derricks were positioned at each panel point, lifting members into place in a precise order. Once a set of truss members was installed, the derricks were moved out to the next panel point to lift the subsequent set of members ahead of itself. At panel points LA5, MA4, and UA4, the derricks were raised into higher positions, in two steps, lifting designated members at each step. This process was continued until the west and east joined.



Key Elevation

Truss joints are identified using industry standards. The first letter notes whether it is an upper, middle or lower joint. The second letter notes which section of the truss it belongs to; anchor arm, cantilever arm, or suspended span. The digit numbers the joint beginning from the point of support.

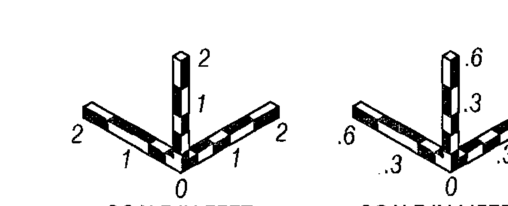
Contruction Sequence

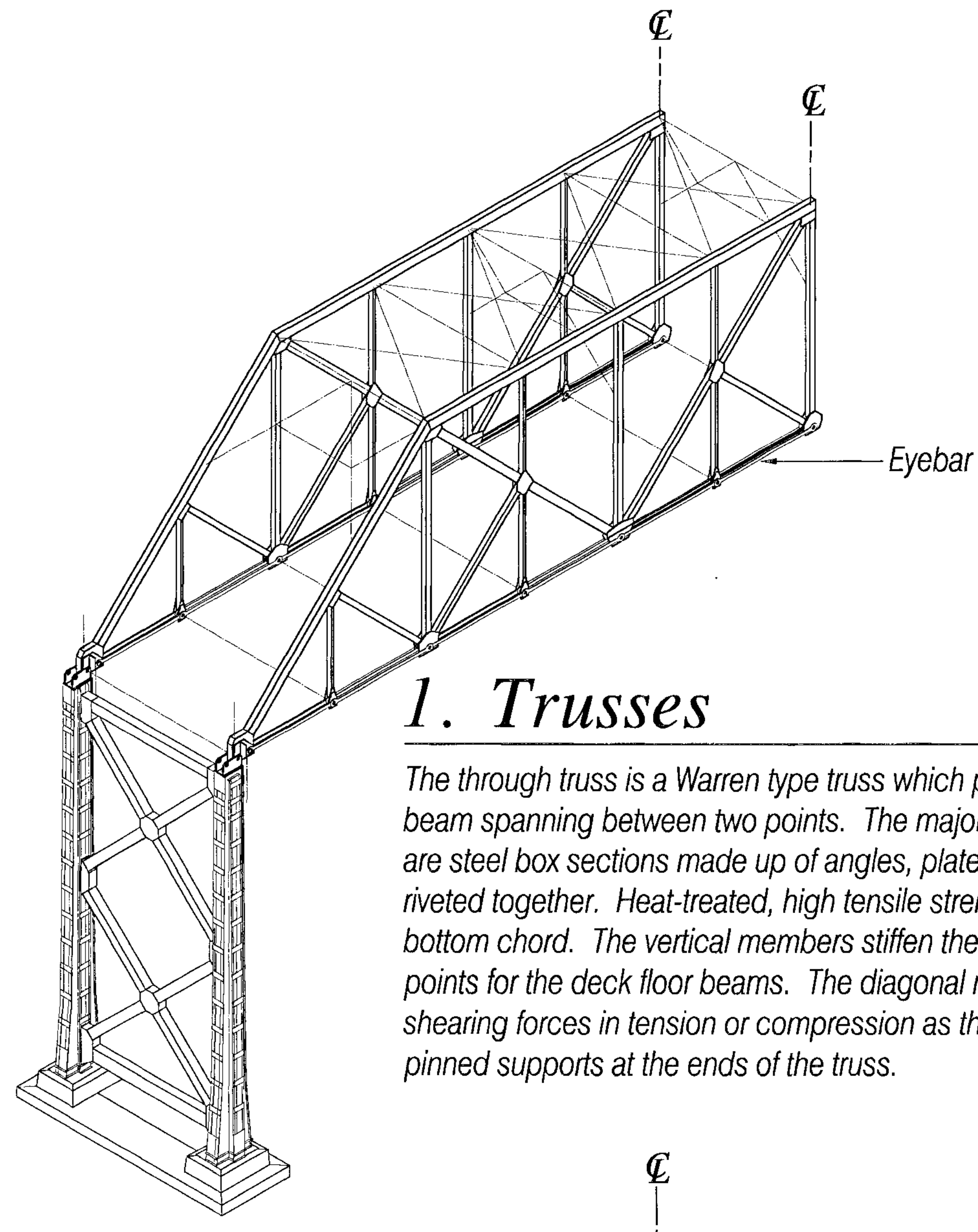
Shown completed to derrick at position "Q".

SCALE IN FEET 0 750 1500

SCALE IN METERS 0 150 300 450

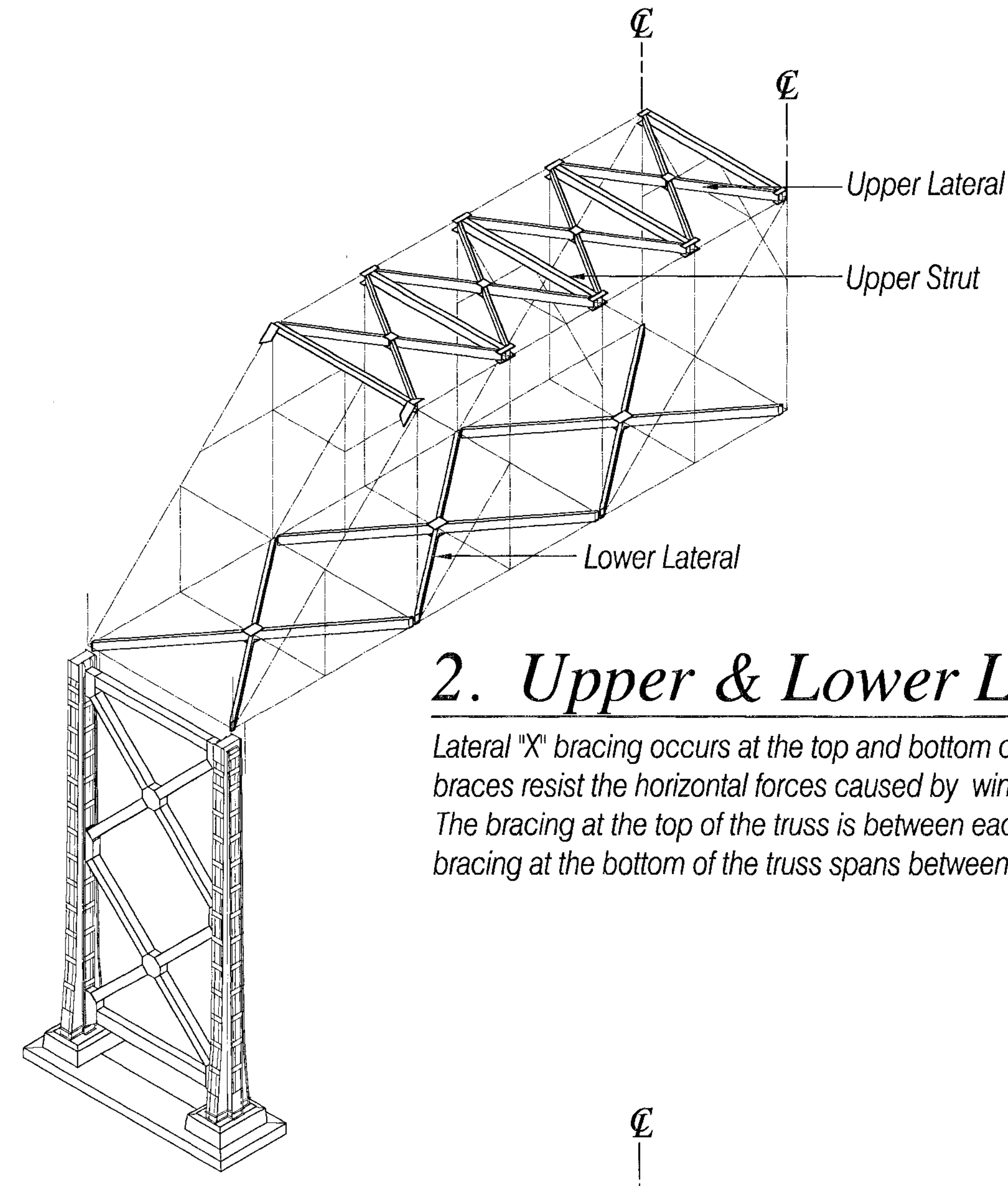
CANTILEVER TRUSS DETAILS





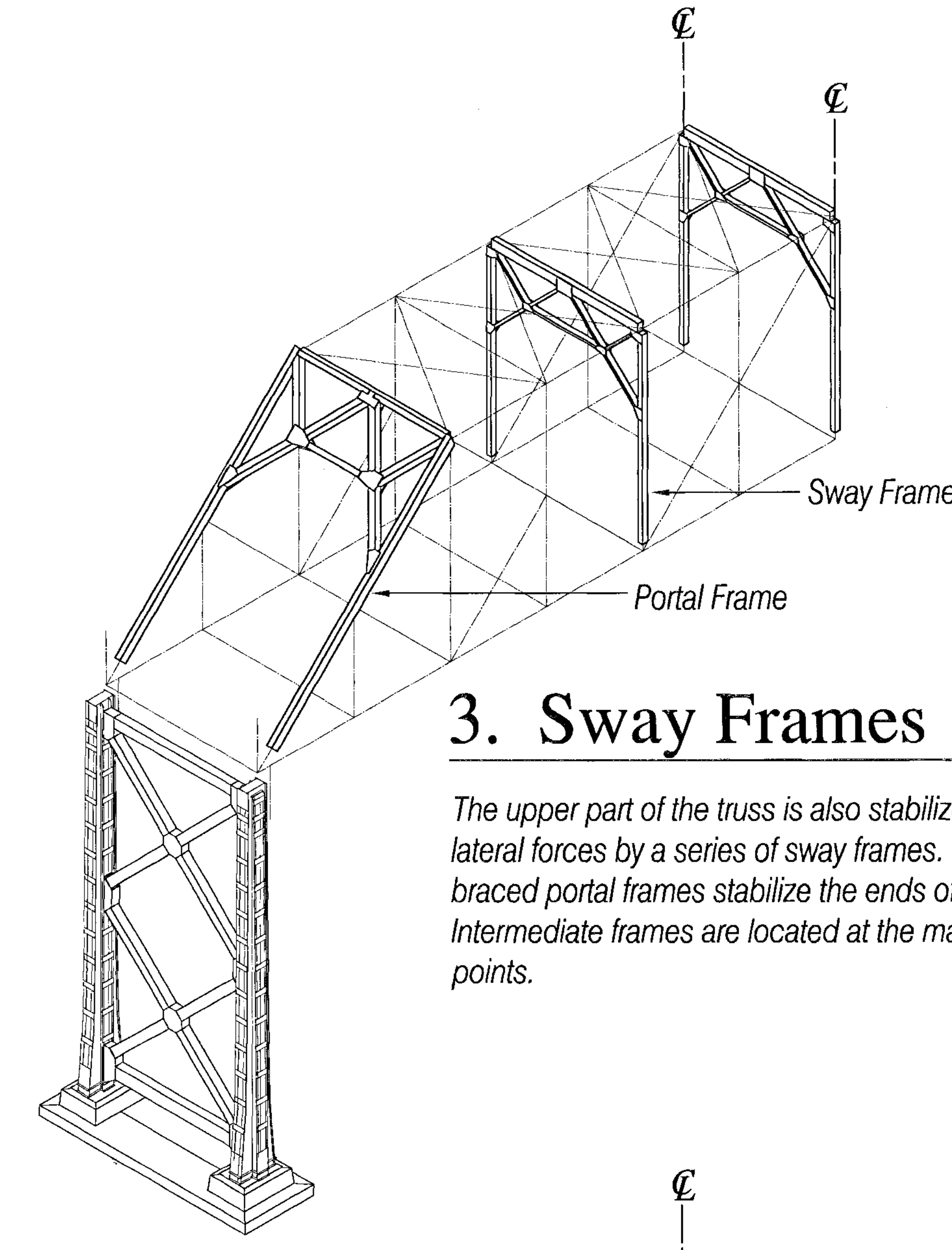
1. Trusses

The through truss is a Warren type truss which performs as a simple beam spanning between two points. The majority of the truss members are steel box sections made up of angles, plates, and flat bar lacing riveted together. Heat-treated, high tensile strength eyebars serve as the bottom chord. The vertical members stiffen the truss and provide anchor points for the deck floor beams. The diagonal members resist the shearing forces in tension or compression as they are distributed to the pinned supports at the ends of the truss.



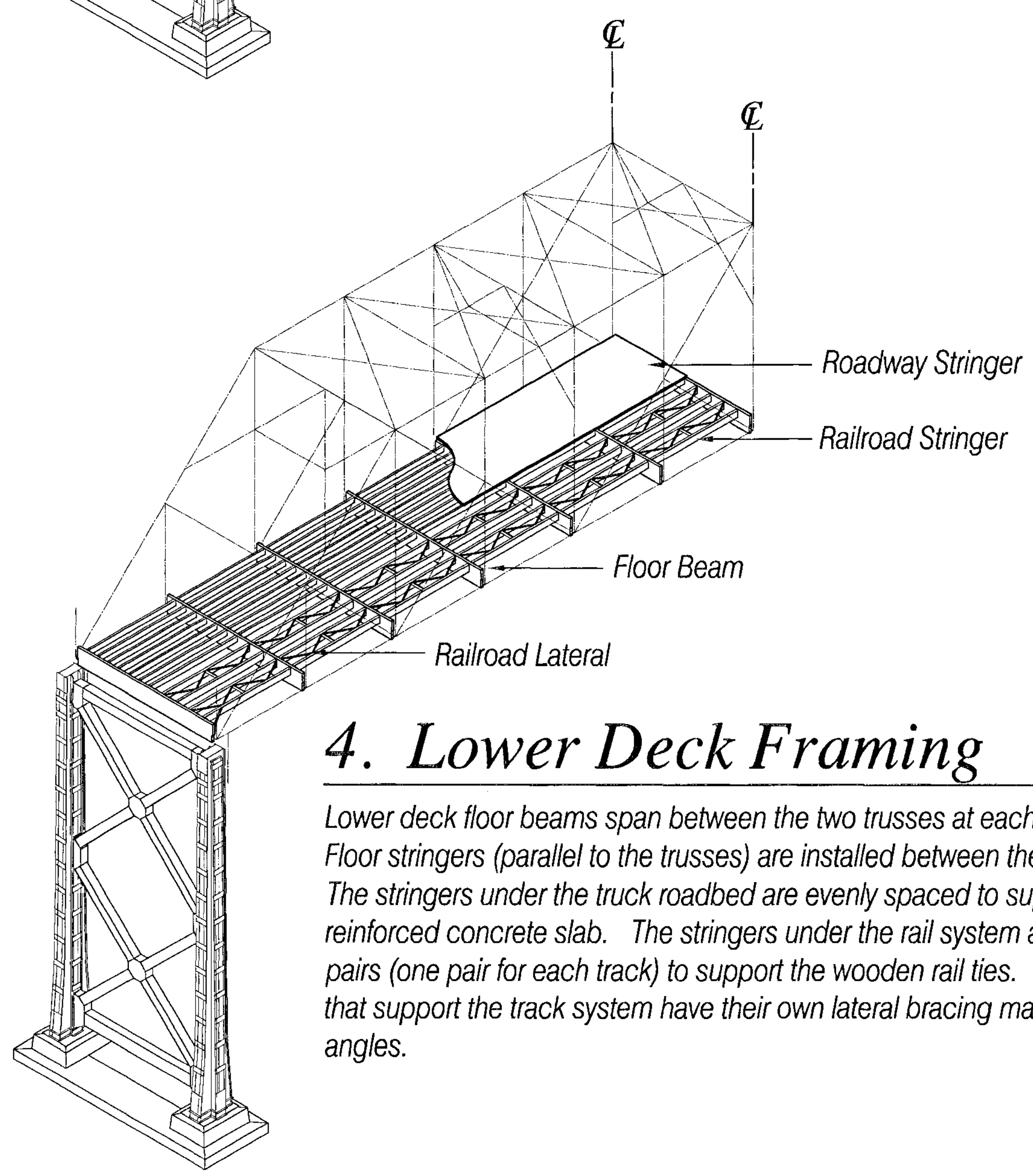
2. Upper & Lower Laterals

Lateral "X" bracing occurs at the top and bottom of the trusses. The braces resist the horizontal forces caused by wind and earthquakes. The bracing at the top of the truss is between each panel point. The bracing at the bottom of the truss spans between two panel points.



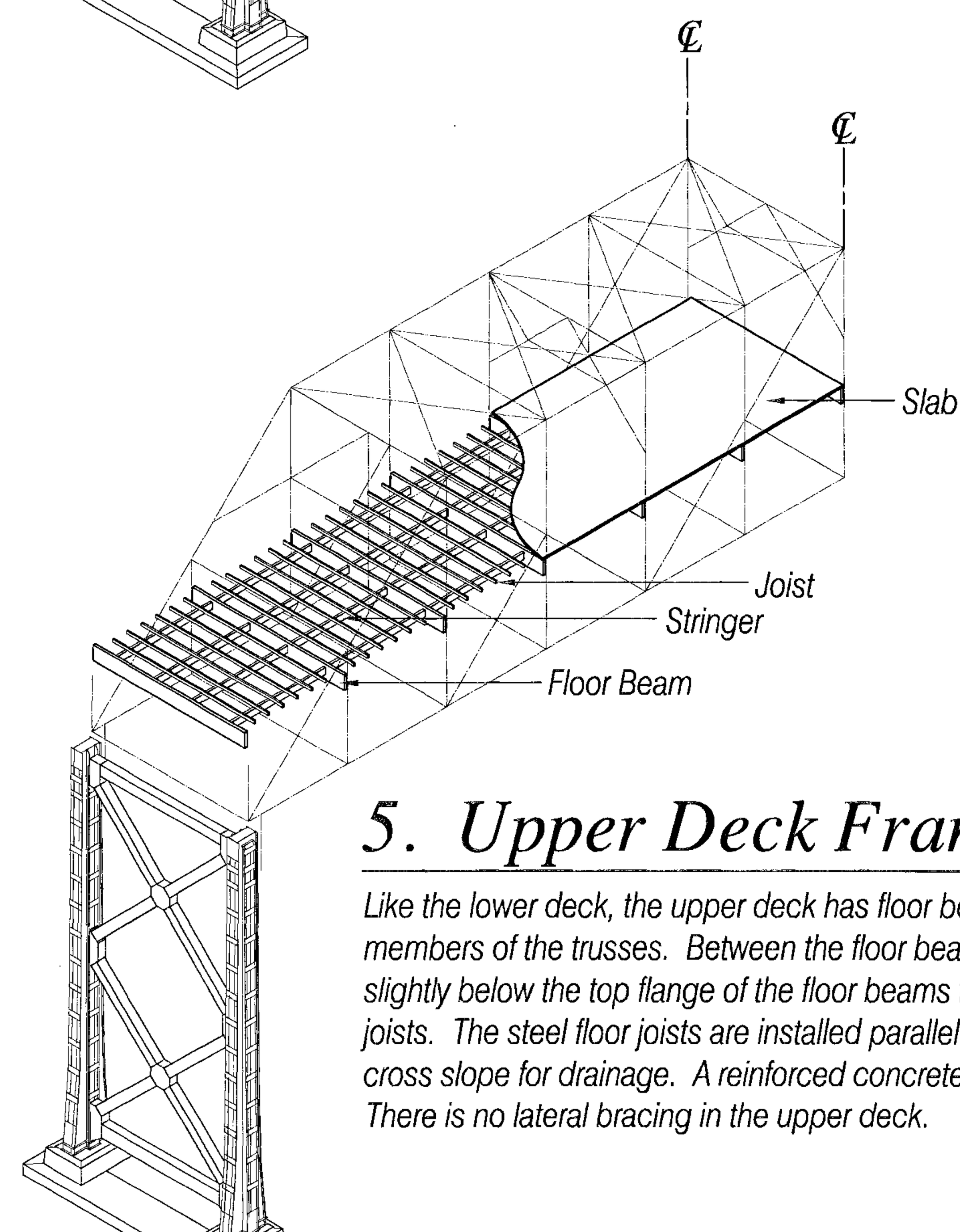
3. Sway Frames

The upper part of the truss is also stabilized against lateral forces by a series of sway frames. These braced portal frames stabilize the ends of the truss. Intermediate frames are located at the major panel points.



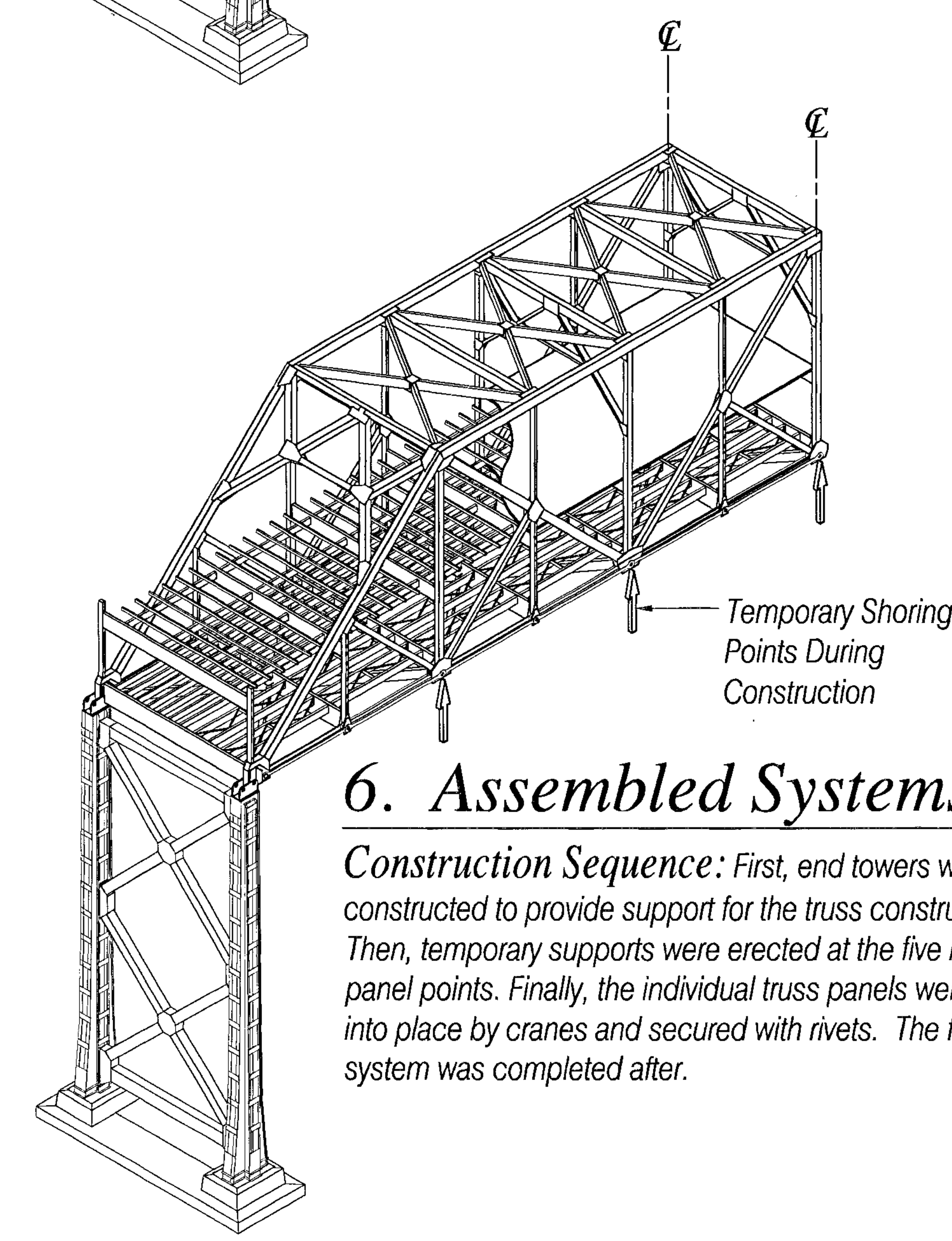
4. Lower Deck Framing

Lower deck floor beams span between the two trusses at each panel point. Floor stringers (parallel to the trusses) are installed between the floor beams. The stringers under the truck roadbed are evenly spaced to support a 6-1/2 in. reinforced concrete slab. The stringers under the rail system are installed in pairs (one pair for each track) to support the wooden rail ties. The stringers that support the track system have their own lateral bracing made of steel angles.



5. Upper Deck Framing

Like the lower deck, the upper deck has floor beams connected to vertical members of the trusses. Between the floor beams are stringers that are set slightly below the top flange of the floor beams to accommodate steel floor joists. The steel floor joists are installed parallel to the floor beams with a cross slope for drainage. A reinforced concrete slab sits on the floor joists. There is no lateral bracing in the upper deck.

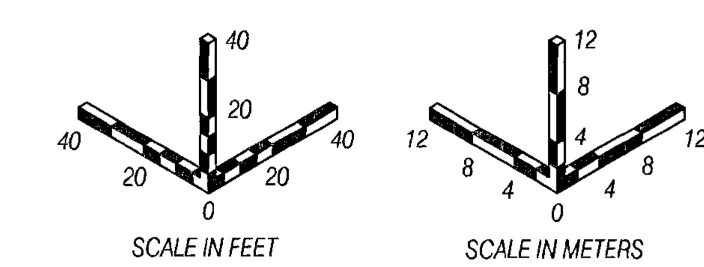


6. Assembled Systems

Construction Sequence: First, end towers were constructed to provide support for the truss construction. Then, temporary supports were erected at the five major panel points. Finally, the individual truss panels were raised into place by cranes and secured with rivets. The floor system was completed after.

THROUGH TRUSS/504' SPAN

(Half Unit Illustrated)



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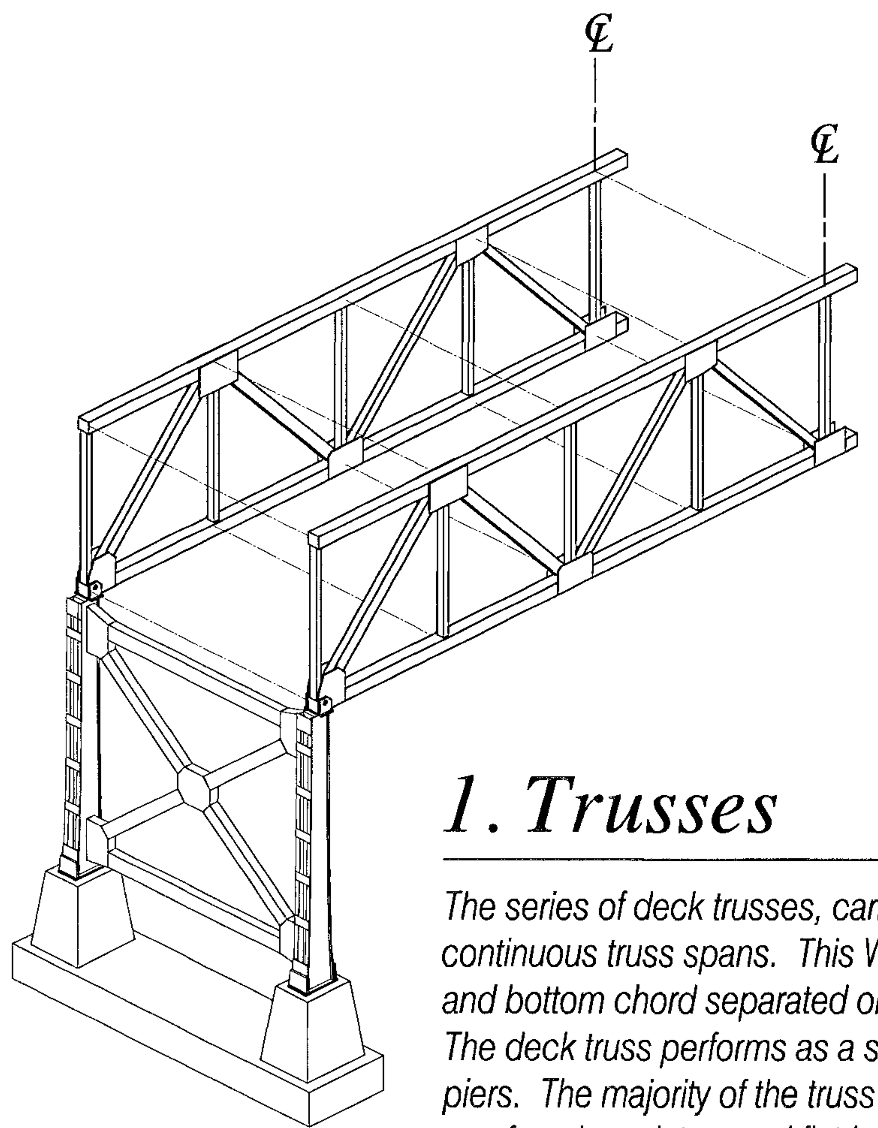
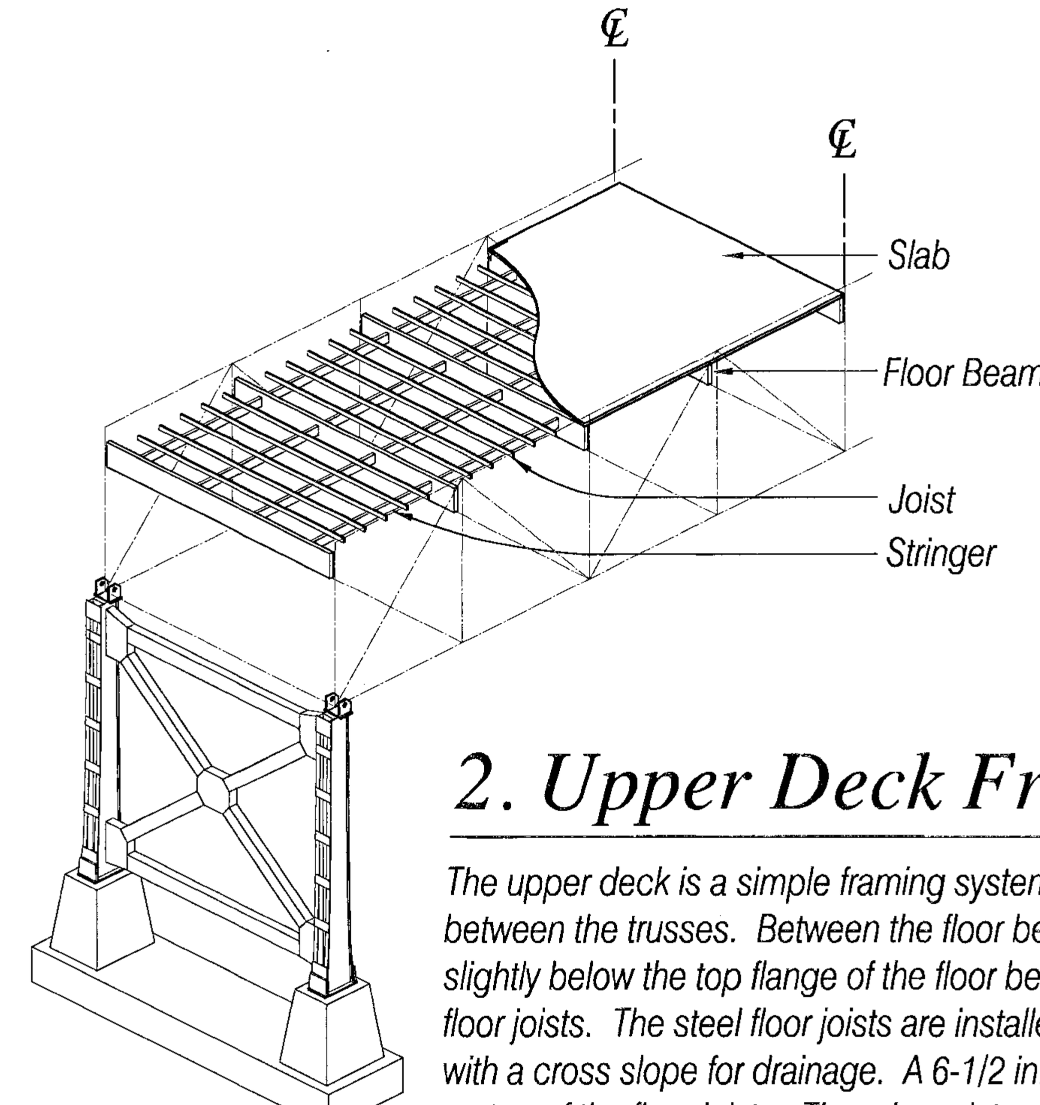
SAN FRANCISCO OAKLAND BAY BRIDGE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR
DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JULIA KIM, 1999   TEXT BY: DAN PETERSON, AIA

TRIM LINE



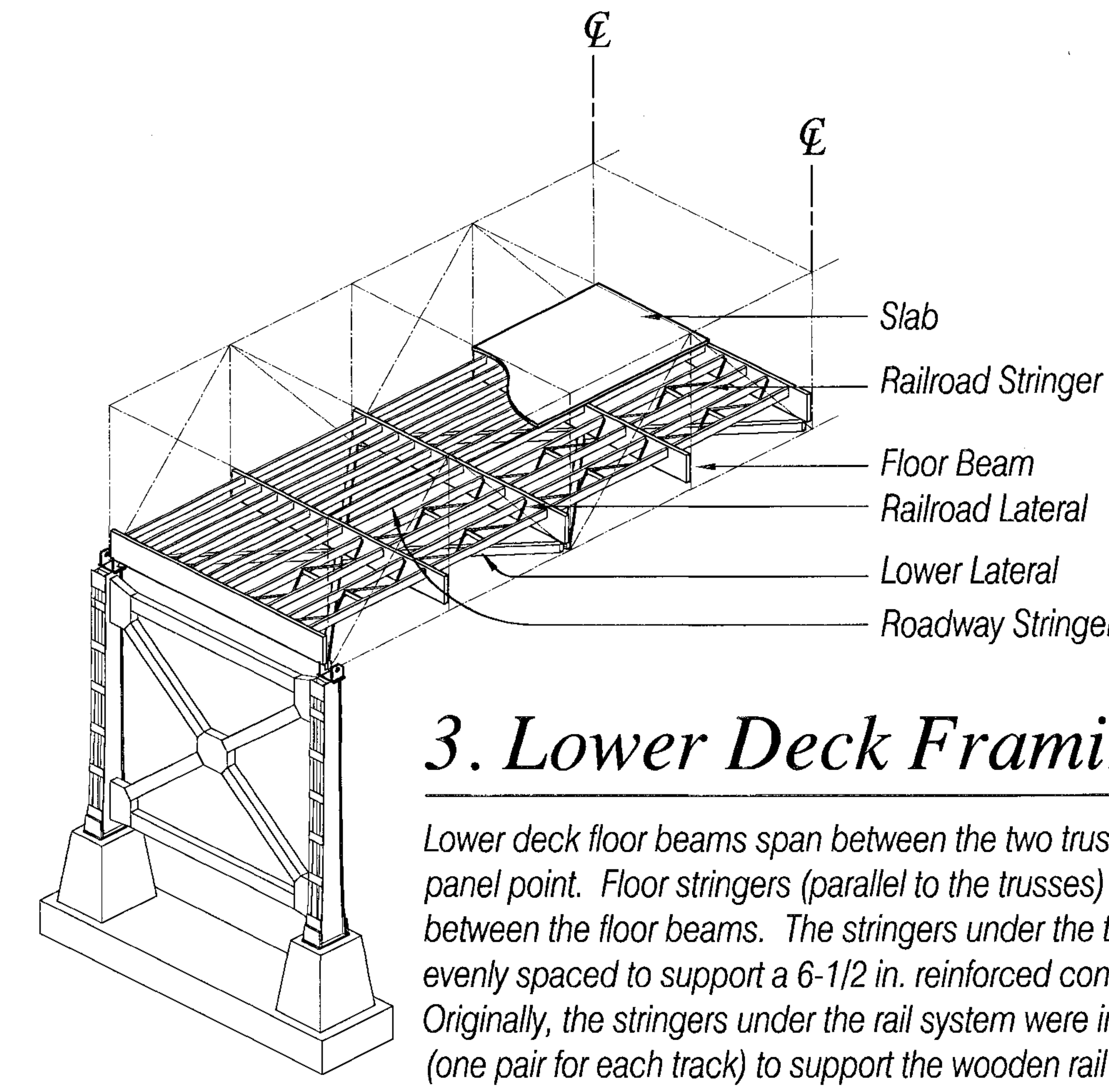
1. Trusses

The series of deck trusses, carrying two decks, are often referred to as continuous truss spans. This Warren type truss has a continuous top and bottom chord separated only by expansion joints over the piers. The deck truss performs as a simple beam spanning between two piers. The majority of the truss members are steel box sections made up of angles, plates, and flat bar lacing riveted together. The vertical members stiffen the truss and provide anchor points for the deck floor beams. The diagonal members resist the shear forces in tension or compression as they are distributed to the support ends of the truss. No eyebars are used in the deck truss spans.



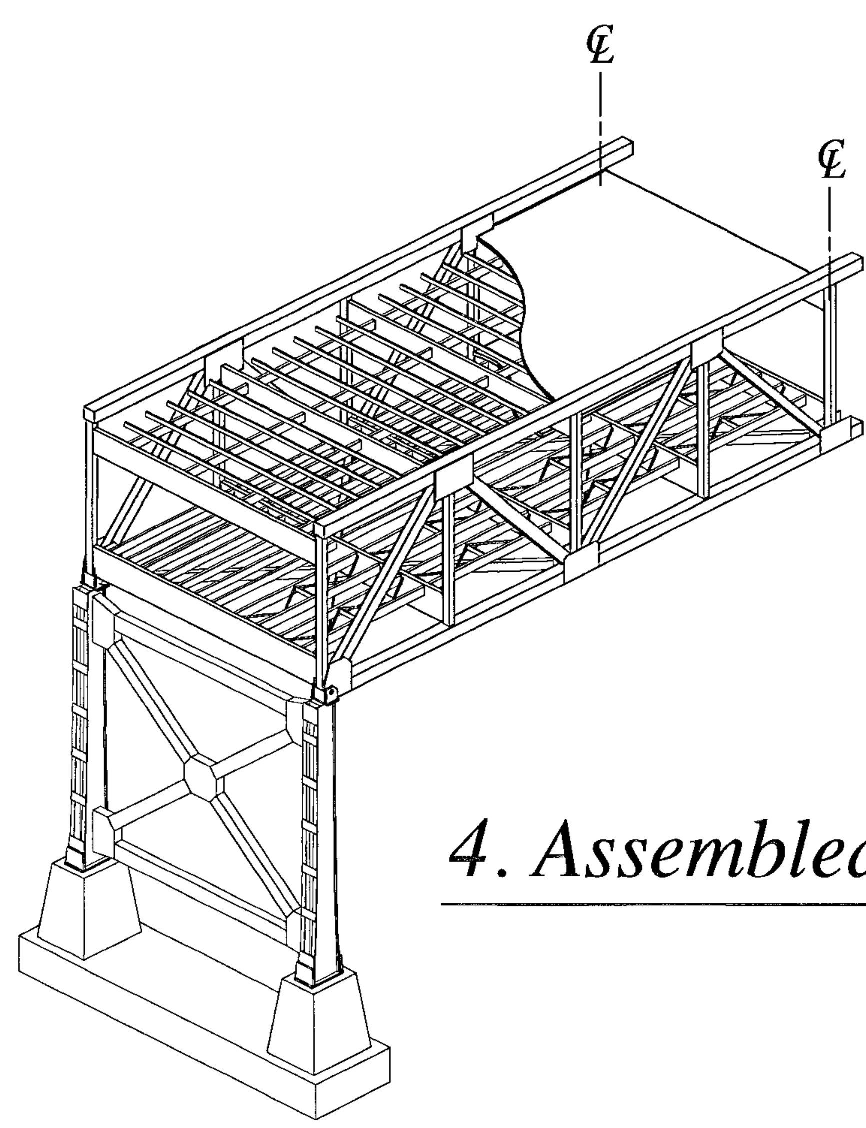
2. Upper Deck Framing

The upper deck is a simple framing system with floor beams spanning between the trusses. Between the floor beams are stringers that are set slightly below the top flange of the floor beams to accommodate steel floor joists. The steel floor joists are installed parallel to the floor beams with a cross slope for drainage. A 6-1/2 in. reinforced concrete slab sits on top of the floor joists. There is no lateral bracing in the upper deck.

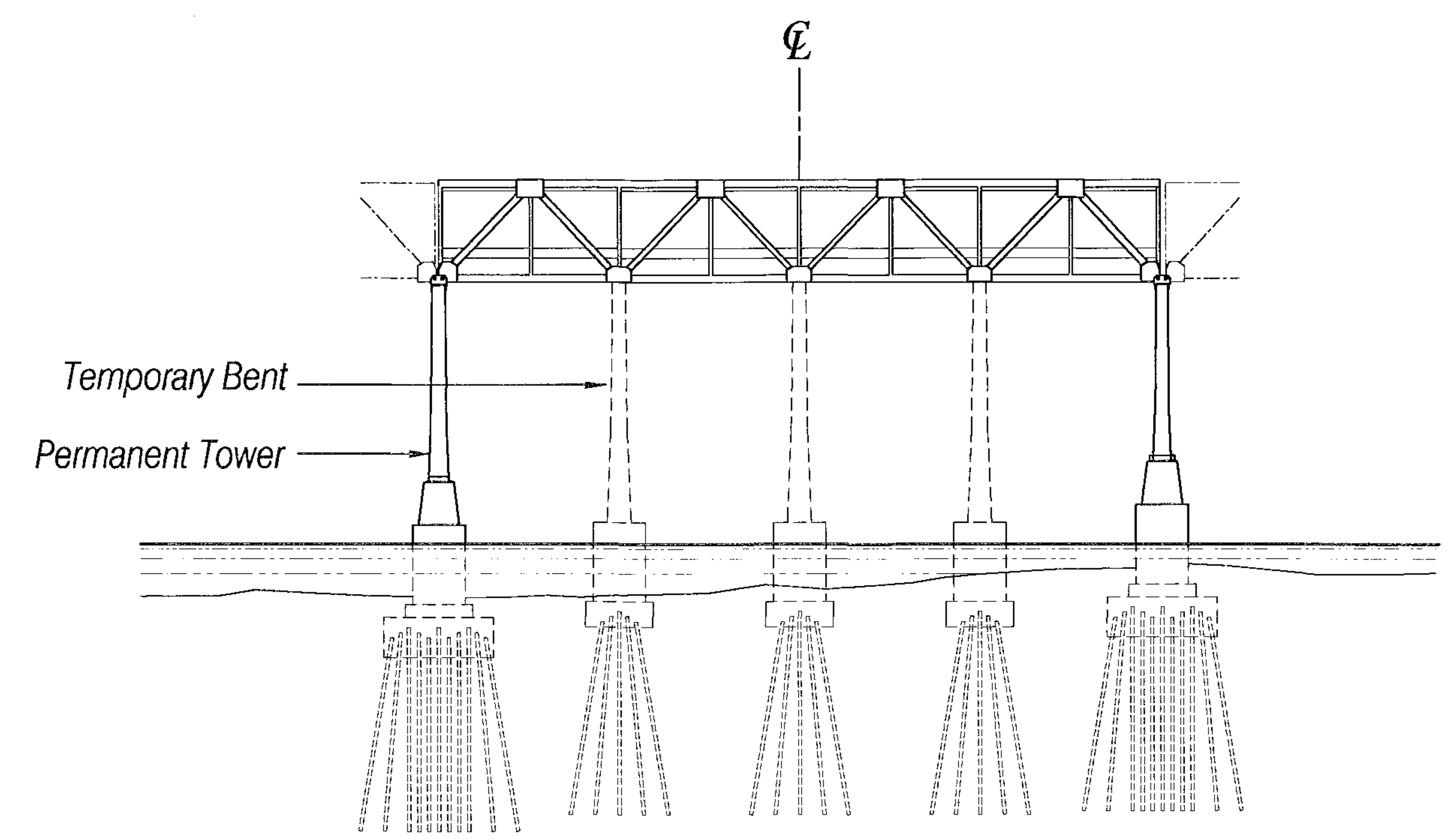


3. Lower Deck Framing

Lower deck floor beams span between the two trusses at each panel point. Floor stringers (parallel to the trusses) are installed between the floor beams. The stringers under the truck roadbed are evenly spaced to support a 6-1/2 in. reinforced concrete slab. Originally, the stringers under the rail system were installed in pairs (one pair for each track) to support the wooden rail ties. Lateral "X" bracing, which resists wind and earthquake loads, occurs in the plane of the bottom truss chords. The "X" bracing covers two panel points. It is interrupted by the deck floor beams forming a series of opposing chevron braces. There is a separate level of lateral bracing between the floor stringers that support the track system.



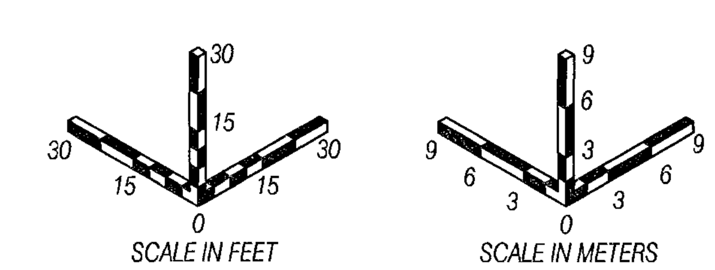
4. Assembled Systems



Construction Sequence

SCALE IN METERS 0 6 12 18
SCALE IN FEET 0 30 60

End towers were first constructed to provide permanent support for the truss system construction. The deck truss was then constructed by building temporary supports under three major panel points, which were left in place until the span was completed. This permitted the individual panels to be raised into place by crane and riveted together.



DECK TRUSS/288' SPAN

(Half Unit Illustrated)

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JULIA KIM, 1999 TEXT BY: DAN PETERSON, AIA

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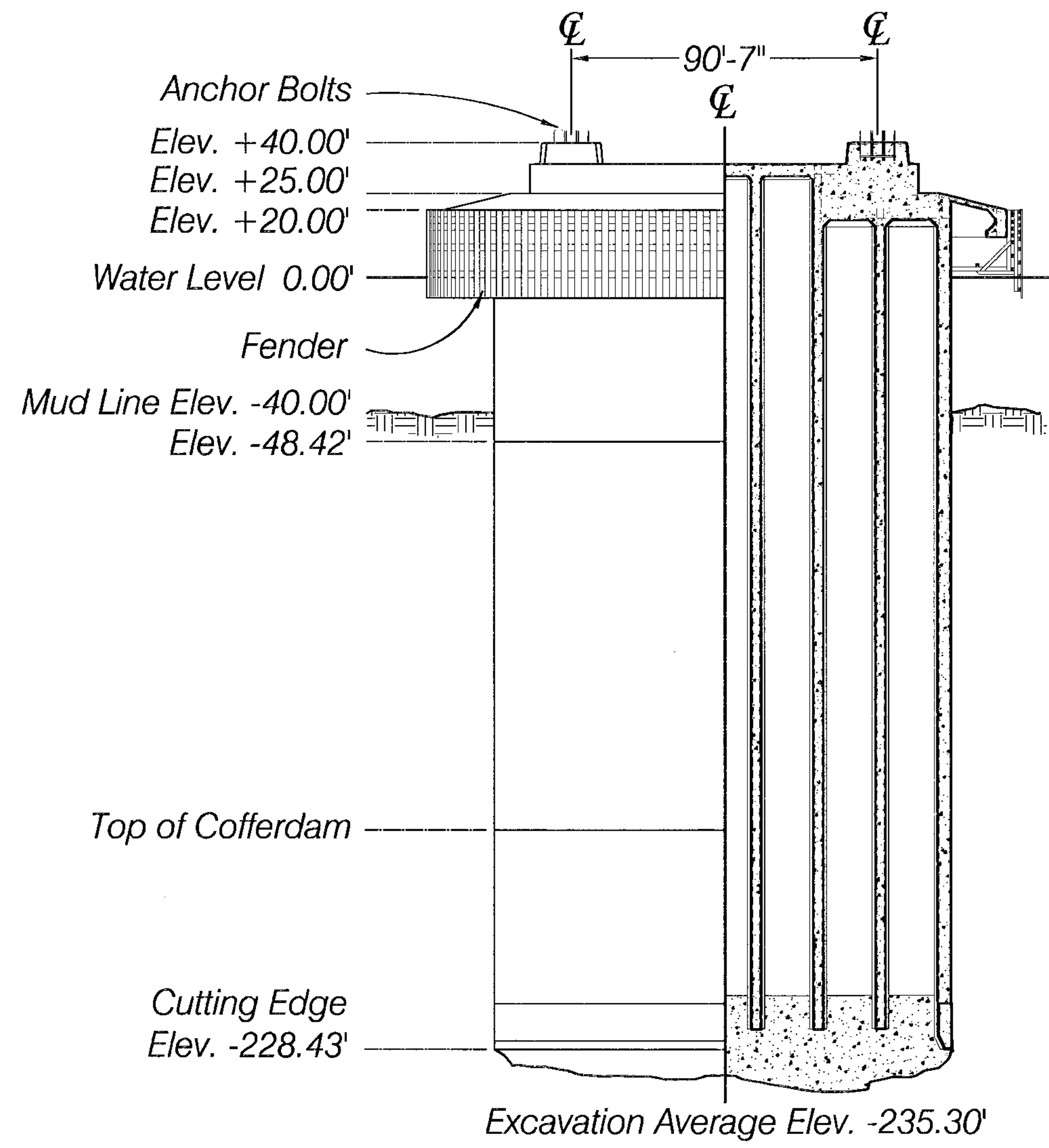
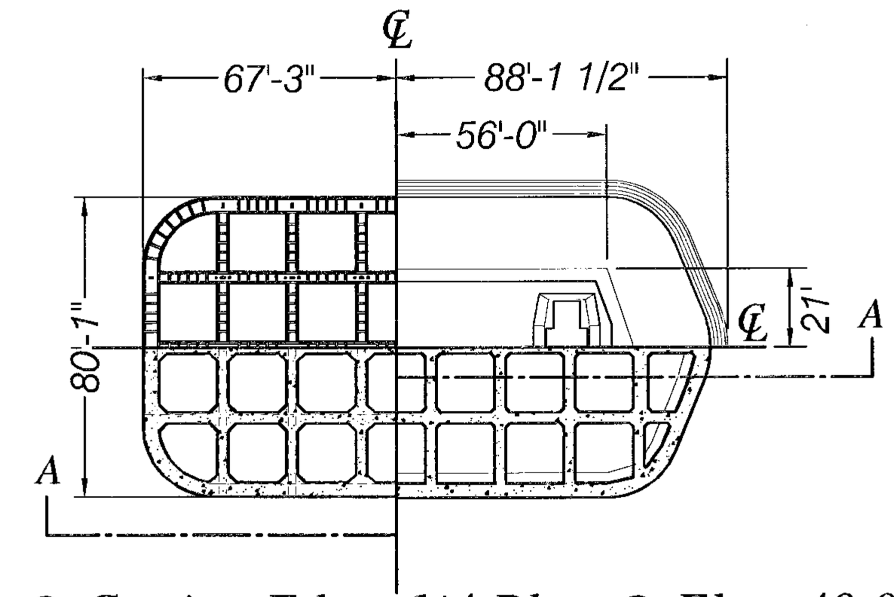
TRIM LINE



Half Elevation /Half Section A-A

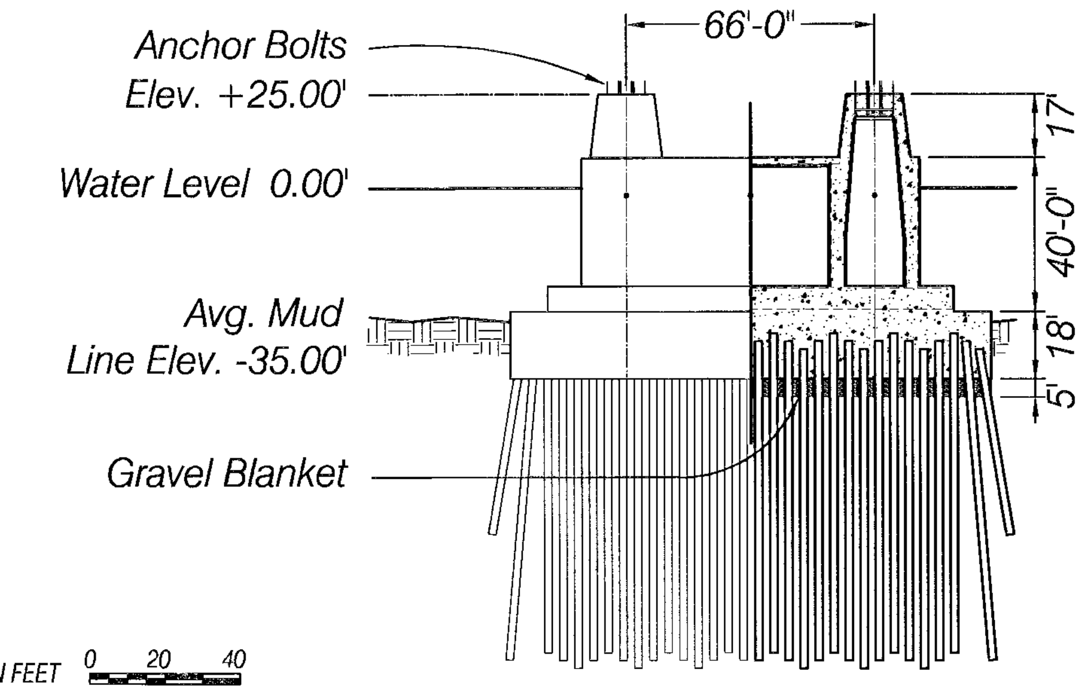


1/4 Plan @ Cutting Edge 1/4 Plan @ Elev. 40.0'
1/4 Plan @ Caisson 1/4 Plan @ Fender

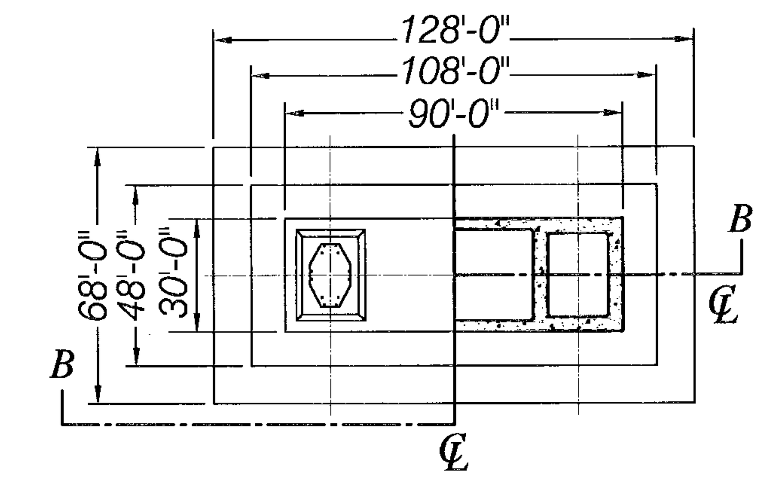
Concrete Caisson (E3 Shown)

SCALE IN FEET 0 20 40
SCALE IN METERS 0 4 8 12

PIER E-1, ON YERBA BUENA ISLAND, AND PIER E-2, JUST OFF SHORE, WERE BUILT WITH A COFFERDAM SYSTEM. PIERS E-3, E-4, AND E-5 UTILIZED A MORE COMPLICATED "FALSE BOTTOM" TYPE CAISSON SYSTEM WHICH WAS BUILT OFF SITE AND FLOATED INTO POSITION. THE WALLS AND CROSS WALLS OF THE CAISSON ASSEMBLY WERE CONSTRUCTED OF STEEL "I" BEAMS AND PLATES RISING 66 FT. ABOVE THE CUTTING EDGE. THE CROSS WALLS FORMED A SERIES OF WELLS, 28 FOR PIER E-3 AND 15 FOR PIERS E-4 AND E-5. THE EXTERIOR WAS MADE OF 2.5 IN. THICK WOOD TIMBERS SUPPORTED BY STEEL AND SEALED TO PREVENT LEAKAGE. A SYSTEM OF WATER-JETS OR "CUTTING JETS" WAS INSTALLED BOTH INSIDE AND OUTSIDE OF THE CUTTING EDGE TO FORCE AWAY MUD. THE CAISSON WAS FLOATED INTO A DOCK AT THE SITE, WHICH CONSISTED OF 6 STEEL PILINGS. TWO ADDITIONAL PILINGS WERE SET AFTER THE CAISSON WAS ANCHORED TO PROVIDE FINAL ANCHORAGE IN FOUR DIRECTIONS. CONCRETE WAS POURED INTO THE WALLS AND CROSS WALLS CAUSING THE FLOATING CAISSON TO SINK. THE CAISSON WAS EXTENDED AS IT SUNK. THE INTERIOR STEEL FORMS, CONSISTING OF STANDARD SECTIONS OF SHEET STEEL WITH ANGLE BARS, WERE REMOVED AND RAISED FOR SUCCESSIVE POURS. ONCE THE CAISSON SETTLED INTO THE MUD, THE REMOVABLE BOTTOMS WERE LIFTED OUT TO PERMIT EXCAVATION OF THE MUD AND COMPOSITE MATERIALS. WHEN THE CAISSON REACHED THE DESIRED LEVEL, THREE WELLS IN PIER E-4 AND E-5 AND 15 WELLS IN PIER E-3 WERE CONTINUED DOWN 15 FT. BELOW THE CUTTING EDGE AND THEN FILLED WITH CONCRETE. THIS PROVIDED A BASE THAT WOULD ALLOW ADDITIONAL CLEANING BY JETTING, INCLUDING SOME UNDERMINING OF THE CUTTING EDGE, WITHOUT THE CAISSON SINKING FURTHER. THE FINAL SEAL CONTINUED 13 FT. INTO THE WELLS.



Half Elevation/Half Section B-B

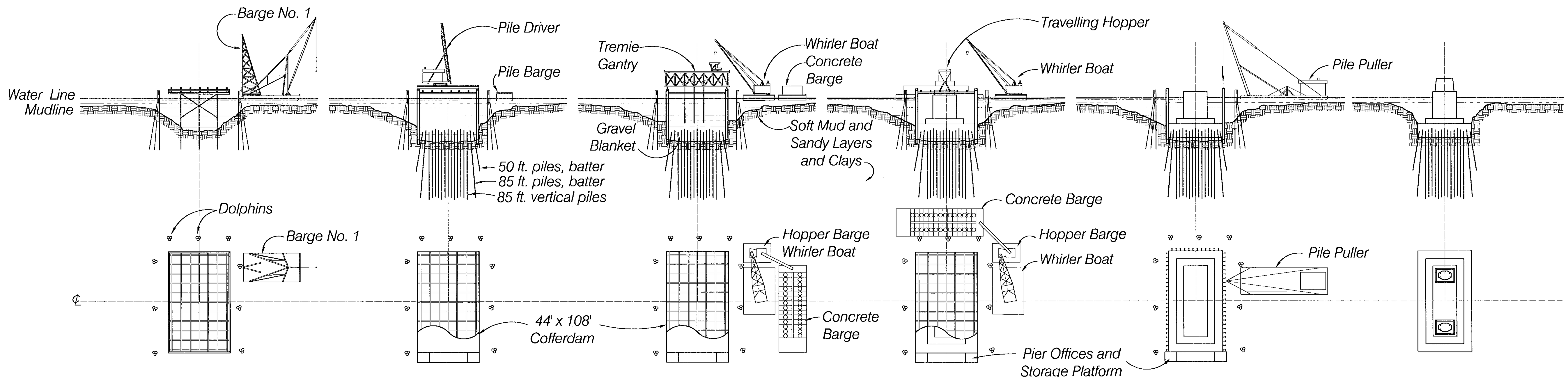


1/2 Plan @ Top 1/2 Plan @ Elev. -26.0'

Wood Foundation Piles (E6 Shown)

SCALE IN FEET 0 20 40
SCALE IN METERS 0 4 8 12

PIERS E-6 THROUGH E-22 ARE SUPPORTED ON WOOD PILINGS DRIVEN INTO THE MUD AND COMPOSITE MATERIAL. PIERS E-23 TO E-39 WERE LOCATED ON LAND AND WERE SUPPORTED BY DRIVEN WOOD PILINGS USING A SHEET PILE COFFERDAM SYSTEM. PIERS E-6 THROUGH E-22 WERE CONSTRUCTED WITH A NEW TYPE OF COFFERDAM CONSTRUCTION THAT REDUCED THE AMOUNT OF CROSS-BRACING AND ELIMINATED THE NECESSITY OF CUTTING OUT AND RE-SHORING THE BRACING DURING CONSTRUCTION.



Phase 1

THE PIER SITE WAS DREDGED TO A DEPTH OF 25 FEET. TEMPORARY PILINGS WERE DRIVEN AROUND THE EXCAVATION TO SUPPORT A VERTICAL FRAME OF STEEL AND TO PROVIDE A GUIDE TO DRIVE THE SHEET PILING. THIS WORK WAS DONE FROM A PILE DRIVER ON A BARGE. TO ANCHOR BARGES AND EQUIPMENT,TEMPORARY MOORING DOLPHINS WERE INSTALLED.

Phase 2

THE COFFERDAM WAS INSTALLED USING 36 IN. STEEL BEAMS (5 FT. 4 IN. ON CENTER) FACED WITH STEEL SHEET PILING. THE AREA WITHIN THE COFFERDAM WAS EXCAVATED TO A DEPTH OF 50 FT. AND THE TEMPORARY PILINGS WERE REMOVED. STEEL WALES WERE INSTALLED AROUND THE TOP PERIMETER OF THE COFFERDAM AND WERE BRACED WITH 14 IN. BY 16 IN. TIMBER BRACING FRAME. A 20 IN. SQUARE TIMBER WITH A TRACK WAS INSTALLED ON TOP OF THE COFFERDAM TO ACCOMMODATE THE REVOLVING PILE DRIVER. PILES WERE DRIVEN AT 4 FT. ON CENTER EACH DIRECTION. ONCE THE PILES WERE DRIVEN, THE MUD WAS JETTED AND PUMPED OUT OF THE COFFERDAM AND A GRAVEL BED (5 FT. MAXIMUM DEPTH) WAS PLACED.

Phase 3

THE CONCRETE SEAL WAS PLACED USING 12 IN. DIAMETER TREMIE CHUTES. TEMPORARY SUPPORTS WERE INSTALLED UNDER THE BRACING FRAME AND THE TREMIE GANTRY WAS SET ONTO THE TRACK USED BY THE REVOLVING PILE DRIVER. THE GANTRY SUPPORTED THE APPARATUS THAT RAISED AND LOWERED THE TREMIE TUBES AND THE TRAVELING HOPPER. THE CONCRETE MIXING EQUIPMENT WAS BUILT ON THREE BARGES: ONE FOR THE HOPPERS AND TWO FOR CONCRETE PLANTS. A FOURTH BARGE HAD A WHIRLER CRANE SYSTEM THAT TRANSPORTED THE MIXED CONCRETE TO THE TRAVELING HOPPER ON THE TREMIE GANTRY. THE TOP OF THE CONCRETE SEAL WAS FINISHED 29 FT. BELOW THE WATER LEVEL. THE SEAL SERVED AS THE BASE FOR THE PIER FOOTING.

Phase 4

THE COFFERDAM WAS DEWATERED. THE FOOTING PAD AND PIER WALLS WERE POURED. THE TOP SLAB WAS POURED AND ALL OF THE CONCRETE FORMS WERE REMOVED. THE COFFERDAM WAS FLOODED.

Phase 5

THE TOP WALES, BRACING, AND SHEET PILING WERE REMOVED. THE SHEET PILING WAS FIRST DRIVEN DOWN TO BREAK IT LOOSE FROM THE CONCRETE SEAL AND THEN PULLED WITH A PILE PULLER ON A BARGE. THE CONCRETE PYLONS FOR THE STEEL SUPPORTS WERE POURED.

Phase 6

THE BRIDGE SEATS ON TOP OF THE PYLONS WERE GROUND TO A MAXIMUM VARIATION OF 1/16 IN. THE MOORING DOLPHINS WERE REMOVED.

Timber Foundation Piles Construction Sequence (Piers E6-E22)

SCALE IN FEET 0 35 70
SCALE IN METERS 0 7 14 21

EAST SPAN FOUNDATION SYSTEMS

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT/JOSEPH ATALLA, 1999 TEXT BY: DAN PETERSON, AIA
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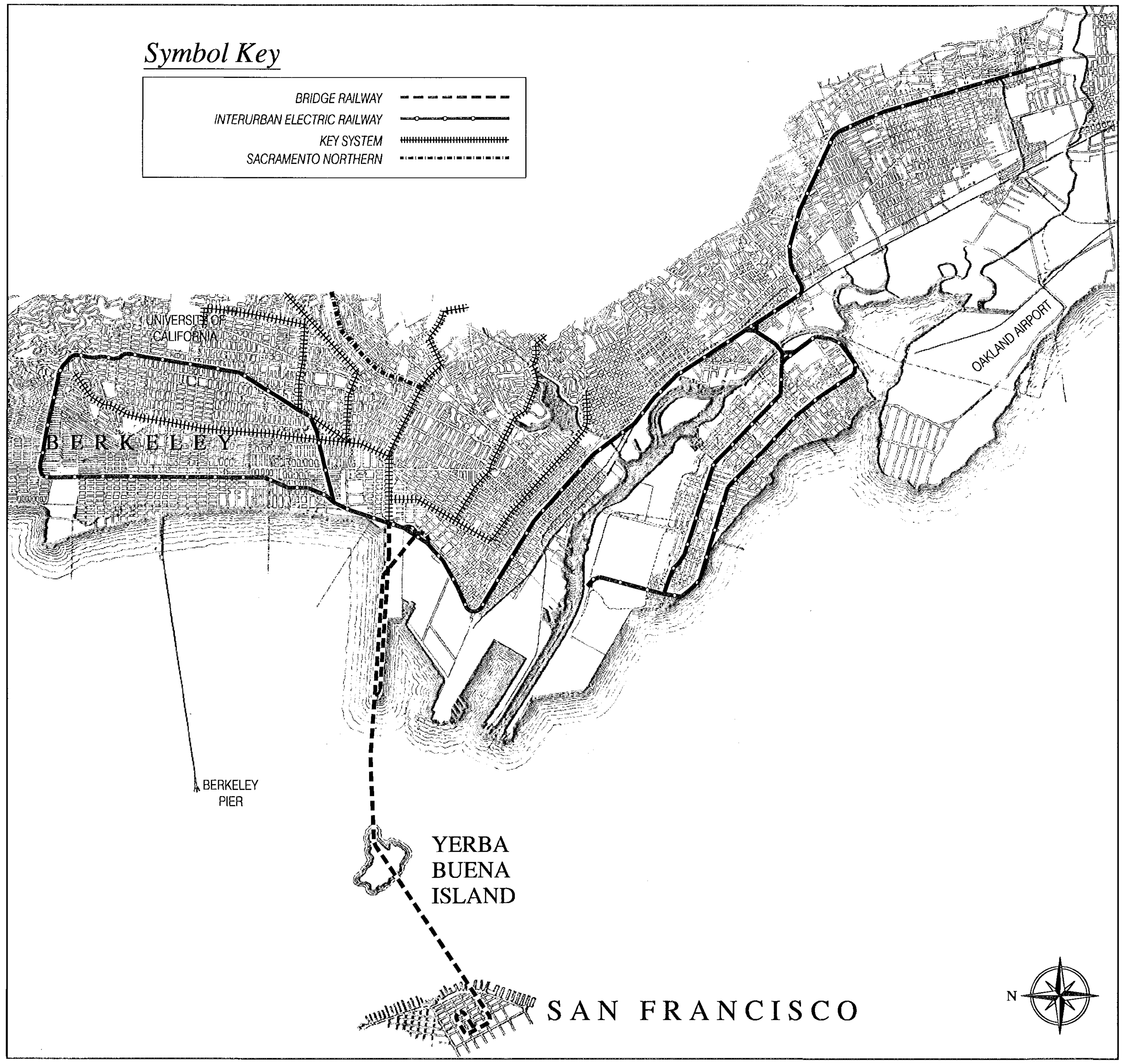
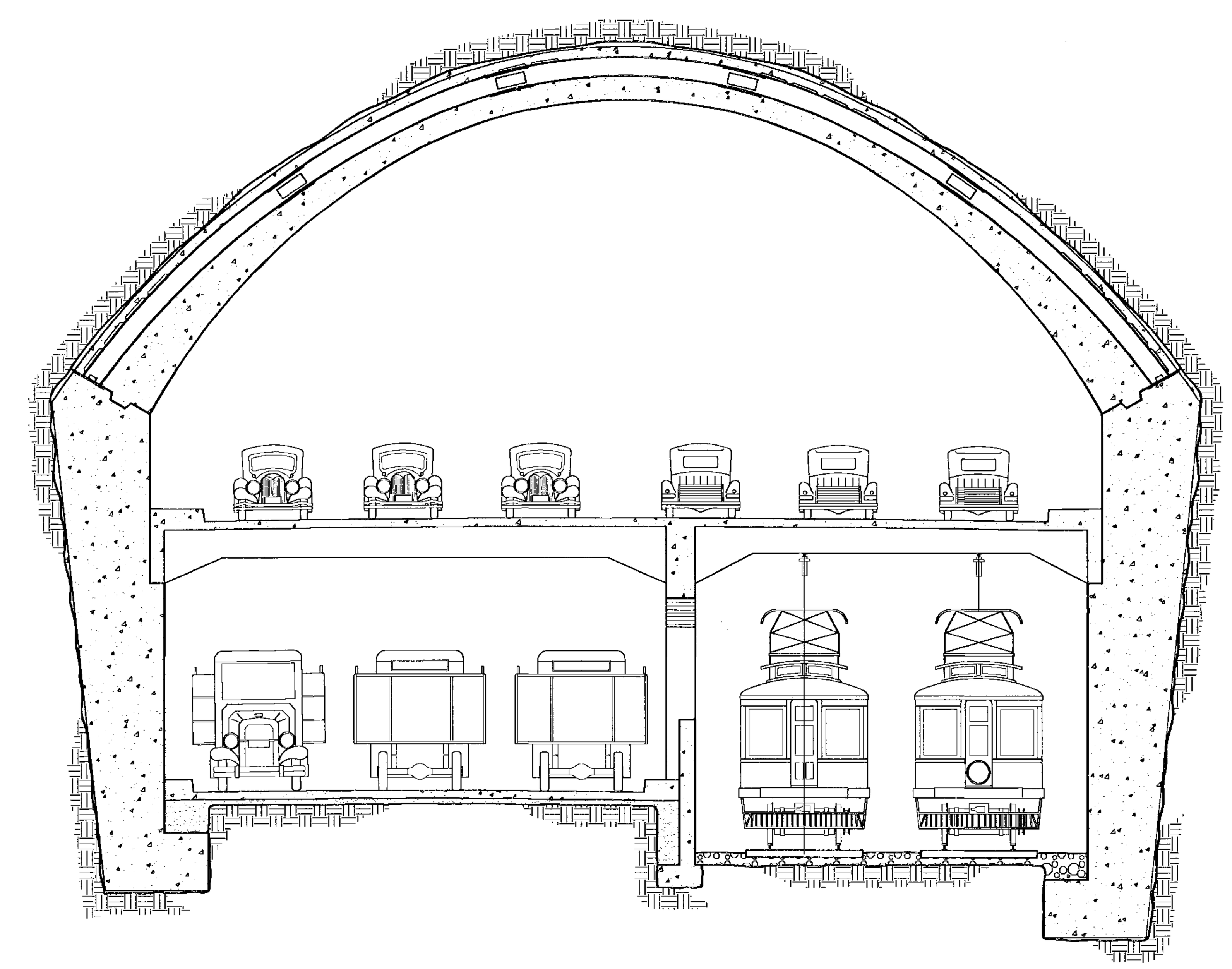


SOURCE: REPORT ON INTERURBAN ELECTRIC RAILROAD FOR SAN FRANCISCO OAKLAND BAY BRIDGE, 1935

Interurban Facilities Via Bridge

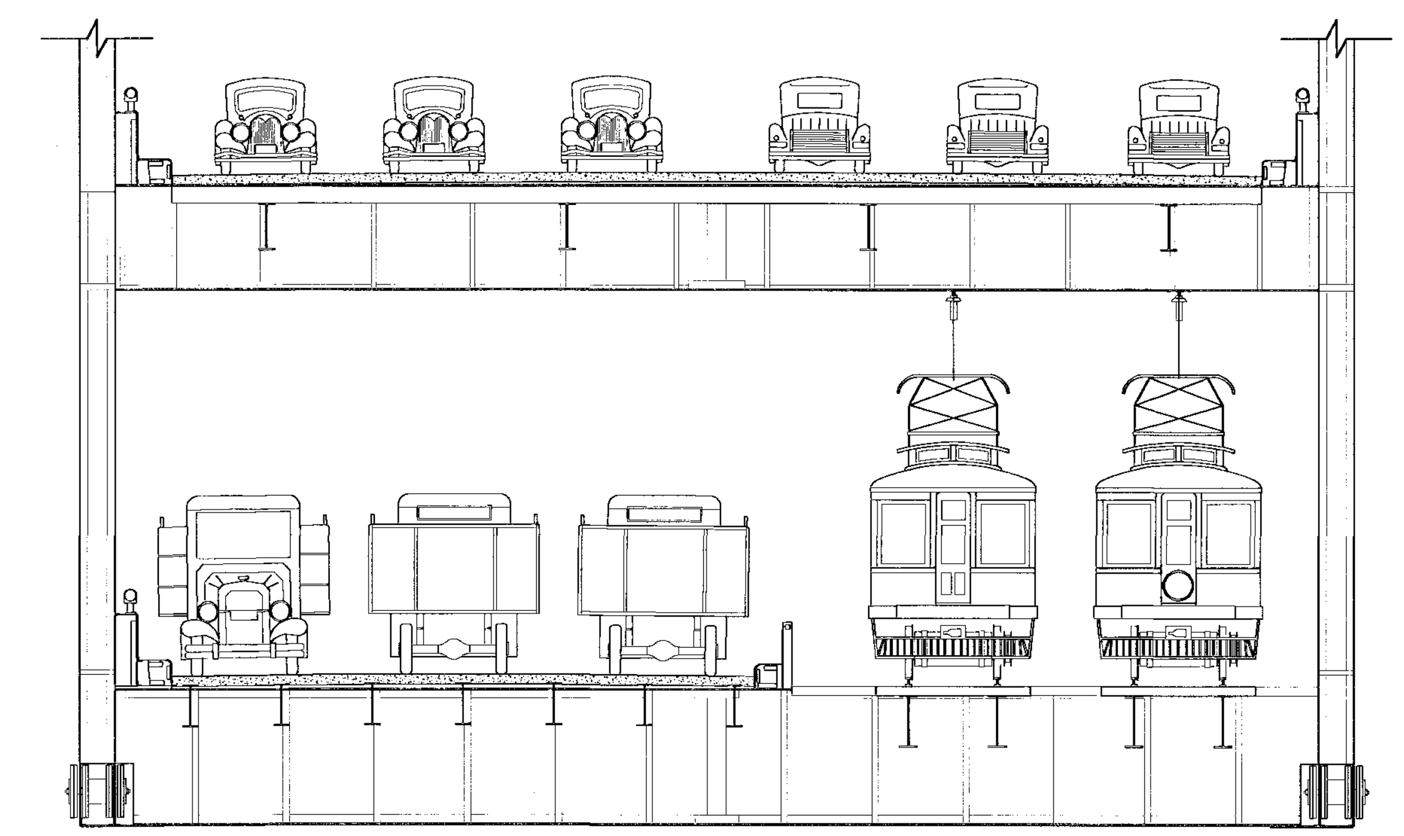
SCALE IN FEET 0 3750 7500
SCALE IN METERS 0 1000 2000

The Bridge Railway was completed in January of 1939. It consisted of the San Francisco Terminal and viaduct loop, connections with existing lines in Alameda County, and all tracks and appurtenances as required to connect the two. In addition, it also included storage tracks in the East Bay yard; the complete power distribution system, except substations; the signal system; telephone system; inspection buildings in the East Bay yard and all incidentals to provide complete facilities for electric interurban service. The design of the railway facilities was based on ten-car trains operating at approximately fifty-six trains per hour on each track. Such a density of traffic had never before been attempted and was made possible by using a four-speed continuous cab-signal and train-control system. Railwork consisted of double tracks and a third rail system. Weight restrictions required an open-deck track construction on the bridge. The Yerba Buena Island crossing and the San Francisco loop (including viaduct and terminal) were of ballasted construction.



Cross Section @ Tunnel

SCALE IN FEET 0 4 8
SCALE IN METERS 0 .8 1.6 2.4



Cross Section @ Through Truss

SCALE IN FEET 0 4 8
SCALE IN METERS 0 .8 1.6 2.4

Ties for the bridge were of redwood, averaging 8 in. by 9 in., spaced on 12 in. centers. Long ties, at 3 ft. spacing, carried planking sidewalks between and at either side of the tracks. Since the bridge is an inherently flexible structure, design of expansion joints was complicated. Movement at the towers of the west crossing was the most extreme, and controlled the design. At these points, in addition to the usual longitudinal motion, there is vertical motion produced by the link connections of the suspended trusses to the towers, a change in the grade line arising form the vertical deflections of the spans, and a pivoting horizontal action arising from the deflection of the spans under lateral forces. This combination of motions required the joints to be universal in their action.

BRIDGE RAILWAY

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT, 1999
SAN FRANCISCO OAKLAND BAY BRIDGE
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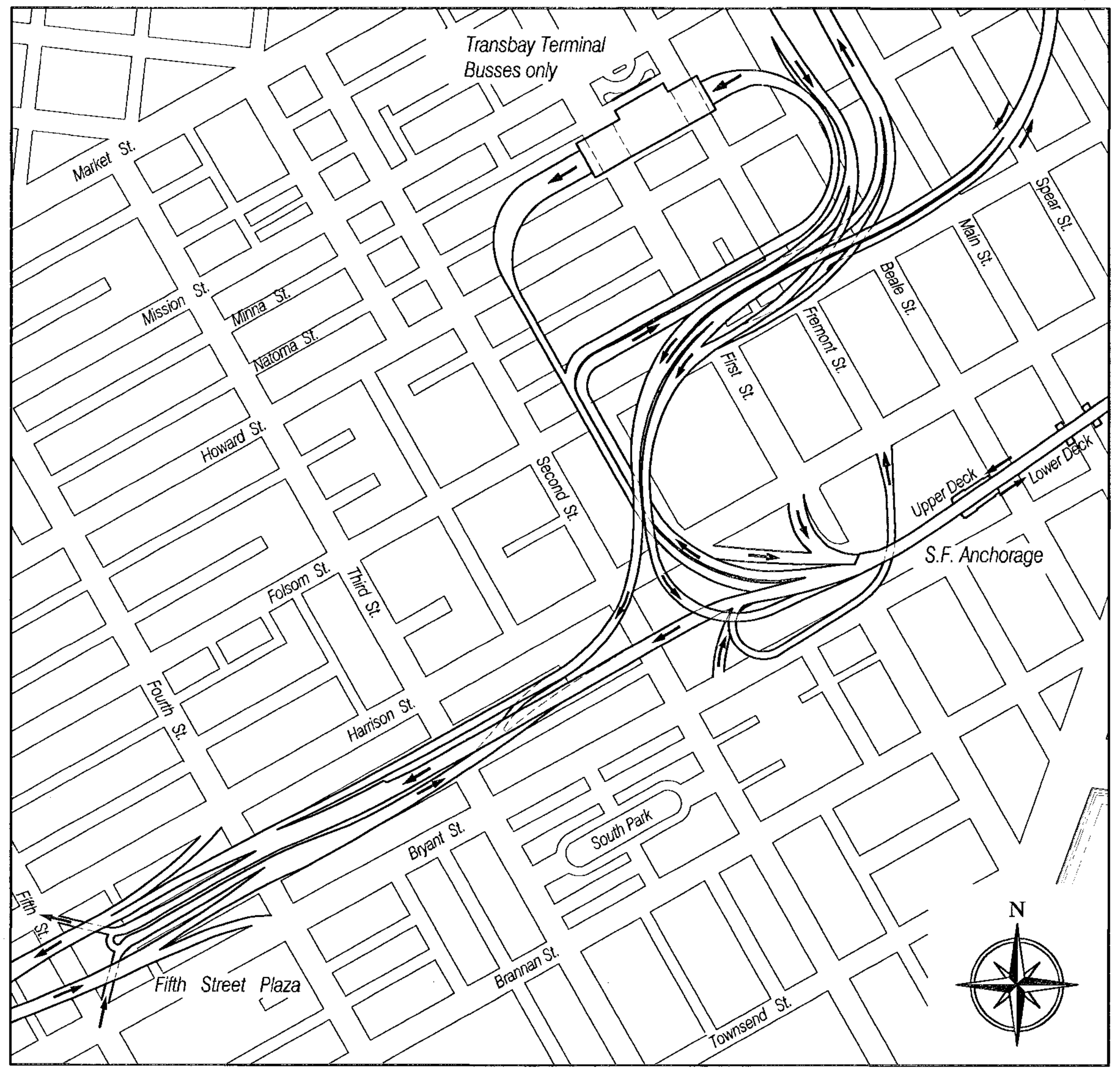
CHANGES 1958-1961

General

The cessation of the bridge railway in 1958 prompted a number of structural and traffic changes. The bridge railways were removed from the lower deck, which was converted to all eastbound traffic including autos, trucks and buses. The upper deck carried the same traffic westbound. At the same approximate time, the S.F. approach was connected to the new S.F. freeway.

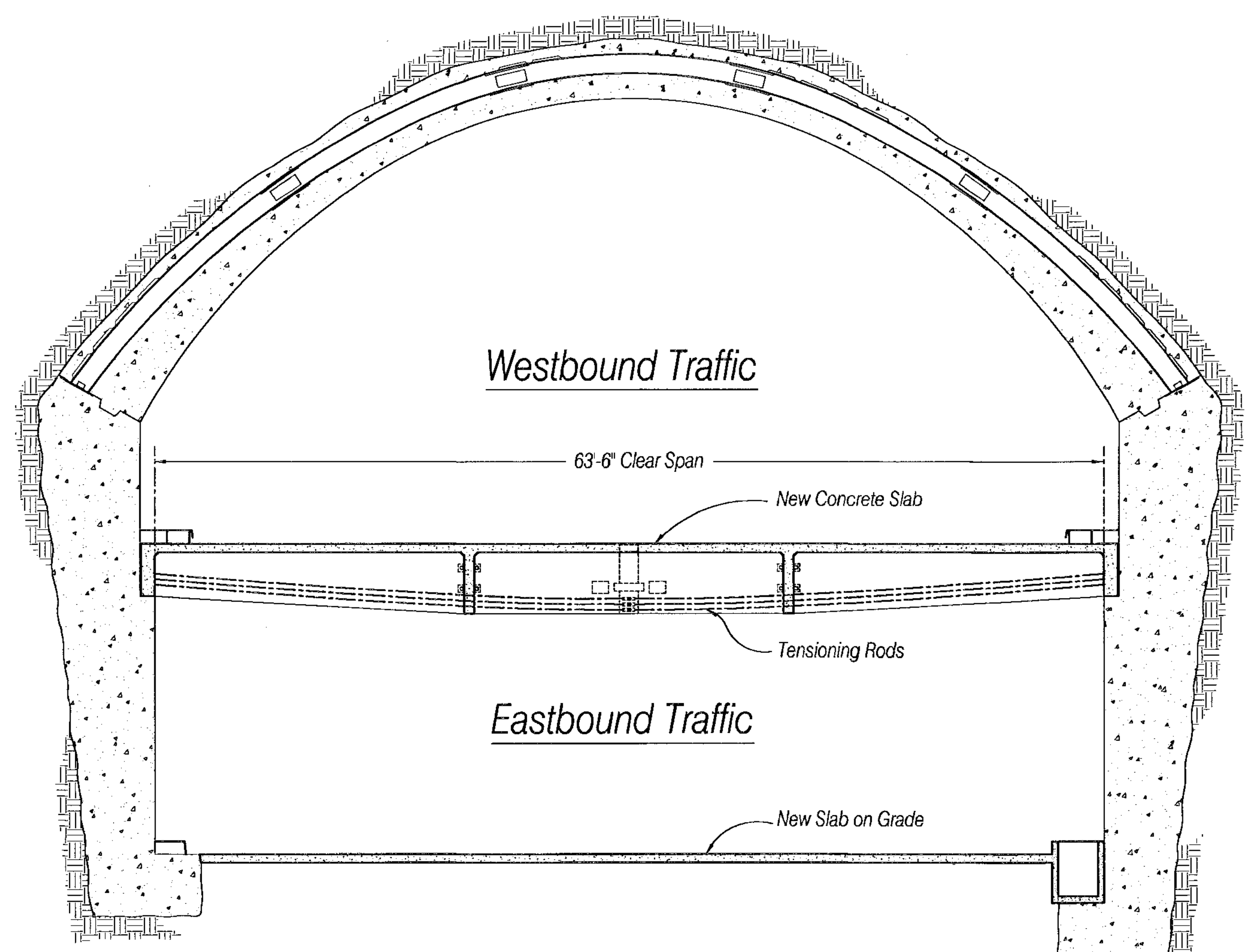


→ ARROW INDICATES DIRECTION OF TRAVEL

San Francisco Approach

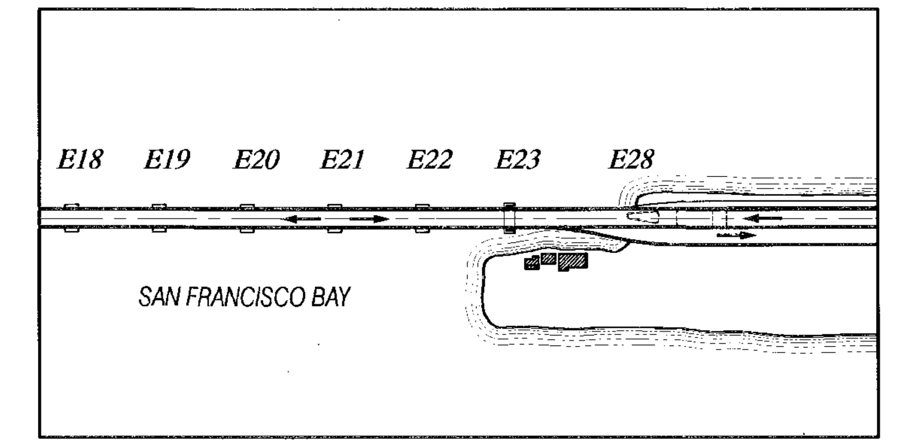
SCALE IN FEET 0 250 500
SCALE IN METERS 0 50 100 150

The remodeling of the San Francisco approach consisted mostly of removing columns that supported the upper deck roadway from the viaduct. The columns would otherwise have obstructed traffic on the new east-bound lower deck. To facilitate removal of the center columns, the outer columns were reinforced with new bolsters/pilasters on the outside faces of the remaining columns at the edges of the roadway, and the floor beams and bent caps were reinforced with new concrete and post tensioning to transfer the loads that were carried by the center column out to the remaining columns. Additional remodeling of the main-line structure consisted of adding a new lower deck west of the Terminal ramps. This new structure consisted of steel plate girders carrying a slab-and-stringer deck supported on reinforced concrete columns.



Section @ Tunnel

SCALE IN FEET 0 4 8
SCALE IN METERS 0 .8 1.6 2.4

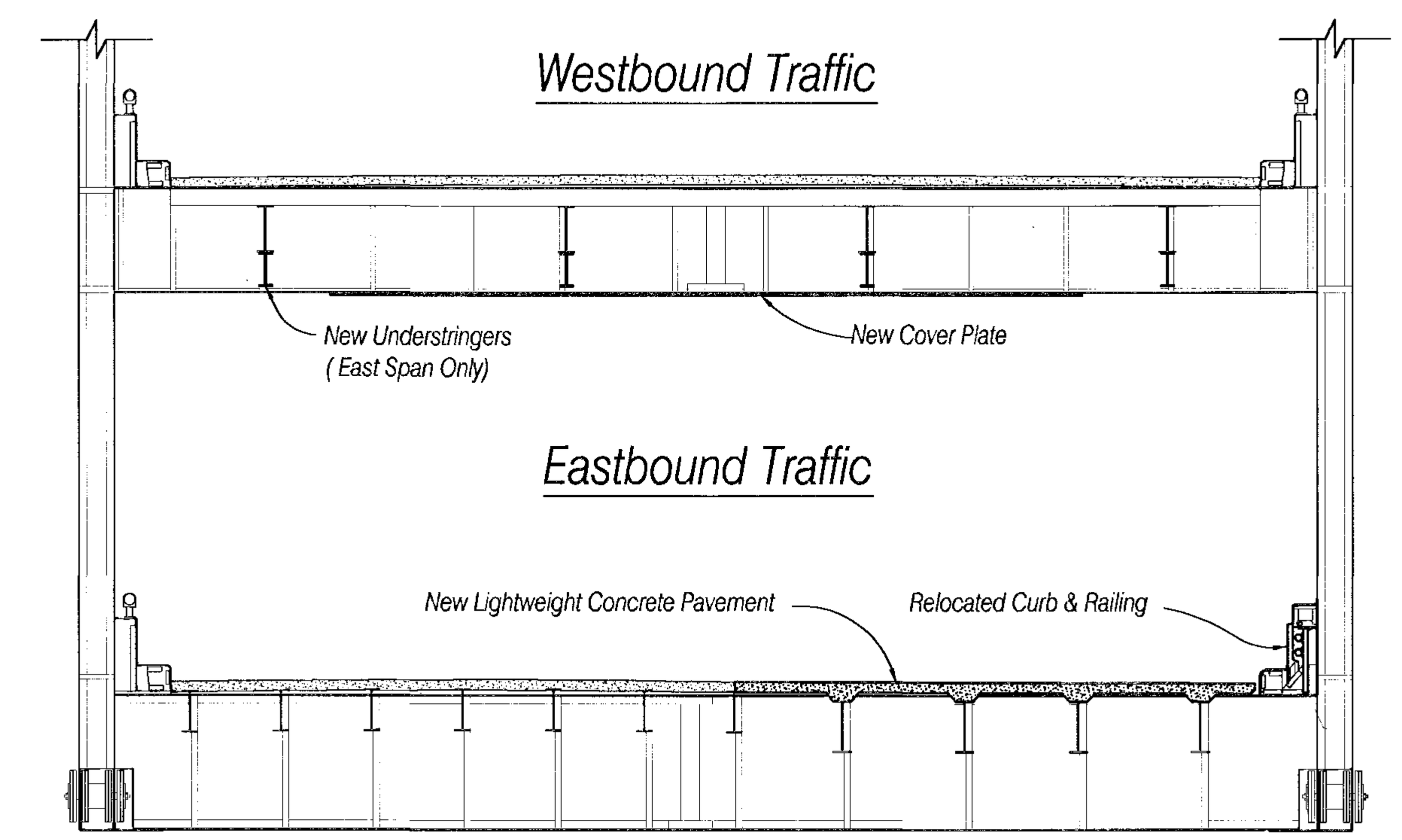


→ ARROW INDICATES DIRECTION OF TRAVEL

East Bay Approach

SCALE IN FEET 0 250 500
SCALE IN METERS 0 50 100 150

The major reconstruction of the East Bay approach was associated with re-framing the alignment transition at the east end. At this location, where the East Bay Crossing is framed with girders in an extended abutment-like structure, the transverse framing was lengthened and strengthened to remove existing columns from the revised highway alignment.



Section @ Through Truss

SCALE IN FEET 0 4 8
SCALE IN METERS 0 .8 1.6 2.4

West Bay Crossing

The remodeling of the West Bay Crossing consisted mainly of reinforcing the upper deck to carry heavier truck loads, and of removing the rails and widening the slab on the lower deck. The upper deck was strengthened by adding cover plates to the transverse floor beams. The cover plates were pre-cut, jacked to a prescribed load, and then fastened with bolts or rivets to the existing lower flange of the floor beams.

Yerba Buena Island Crossing

The remodeling consisted mostly of work associated with removing the columns that supported the middle of the upper deck and lowering the upper deck so that adequate headroom would be provided for tall trucks on the upper deck. Additional work was performed to bring both sides of the lower deck to a uniform grade for one-way traffic use. The column removal and upper deck lowering work required replacing the upper deck floor with a new floor at a lower elevation that spanned all the way across the tunnel without intermediate support. The new floor consisted of pretensioned concrete tees, that were installed one at a time beneath a short temporary bridge that allowed both decks to remain in service during the reconstruction.

East Bay Crossing

The remodeling of the East Bay Crossing consisted mainly of reinforcing the upper deck to carry heavier truck loads, removing the rails and widening the structural slab on the lower deck, and re-framing the transition at the east end so that five lanes of traffic can exit the lower deck to the south. The upper deck was strengthened by adding cover plates to the transverse floor beams (similar to the procedure used on the West Bay Crossing) and by adding additional rolled girder shapes beneath the original stringers to increase their strength.

BRIDGE RECONSTRUCTION

DRAWN BY: ZACHARY D. GOODMAN, ARCHITECT, 1999
SAN FRANCISCO OAKLAND BAY BRIDGE
CALIFORNIA DEPARTMENT OF TRANSPORTATION
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

SAN FRANCISCO OAKLAND BAY BRIDGE (OAKLAND-SAN FRANCISCO BAY BRIDGE)
SPANNING THE SAN FRANCISCO BAY SAN FRANCISCO CITY AND COUNTY CALIFORNIA

HISTORIC AMERICAN ENGINEERING RECORD
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