



The Historic American Engineering Record for: **THE SAN FRANCISCO OAKLAND BAY BRIDGE**

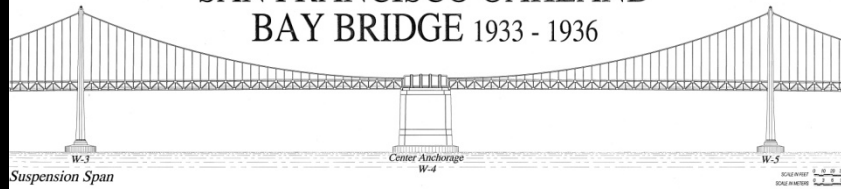
Compiled by Chris Austin
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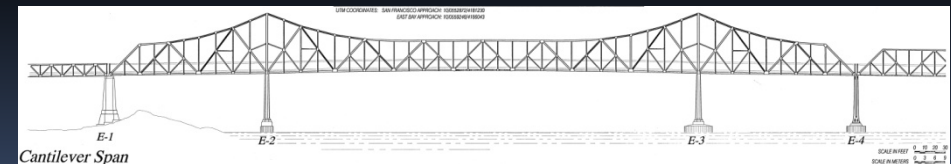
The San Francisco-Oakland Bay Bridge is extensively documented in the HAER collection with over 400 photos and 20 drawings. Not all of this information is included here in this slideshow. However, you can view the record in its entirety by clicking here:

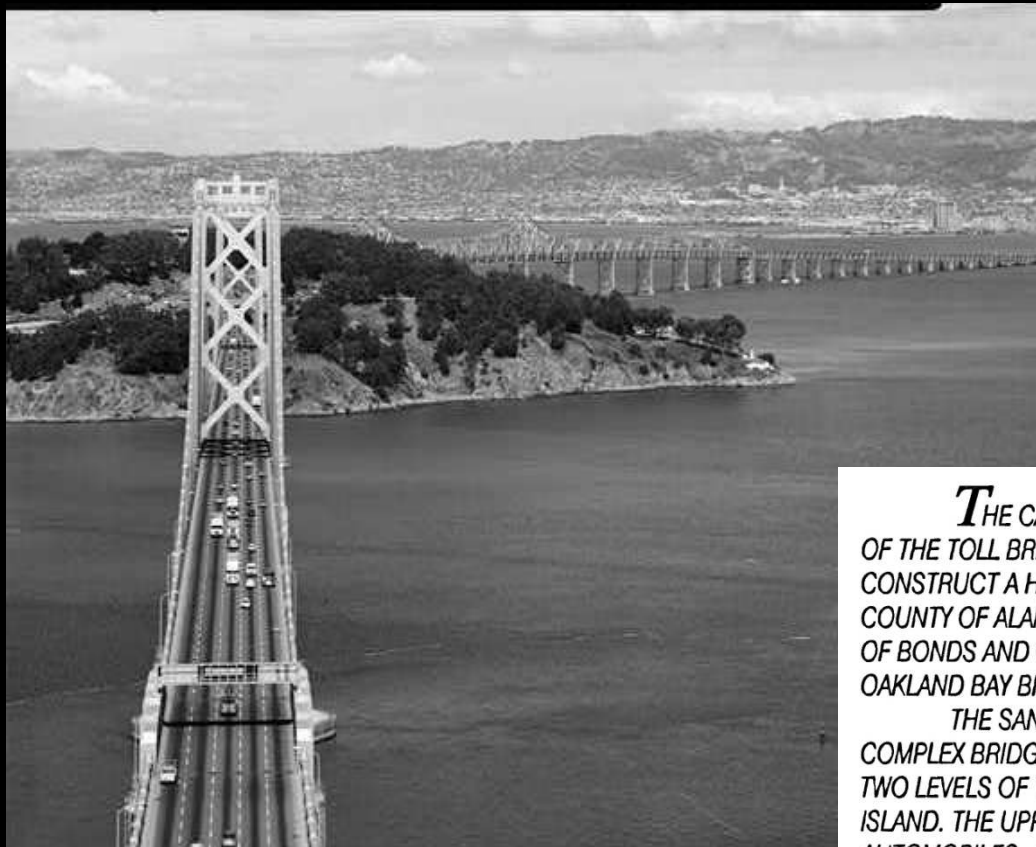
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SAN FRANCISCO OAKLAND BAY BRIDGE 1933 - 1936



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.





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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.



Vicinity Map (NOT TO SCALE)

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

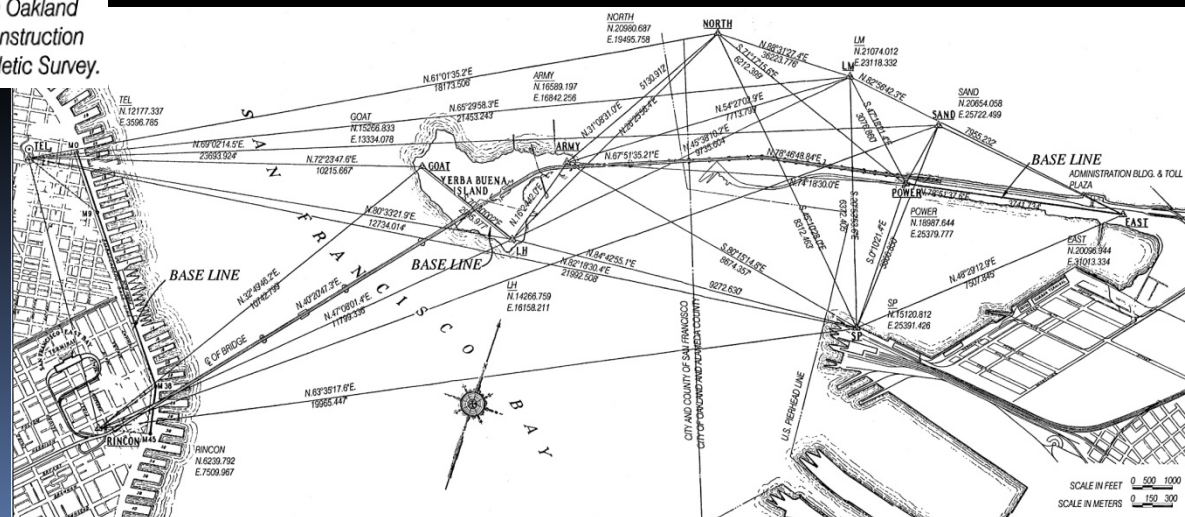
Triangulation Net

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.

Aerial view, 1997

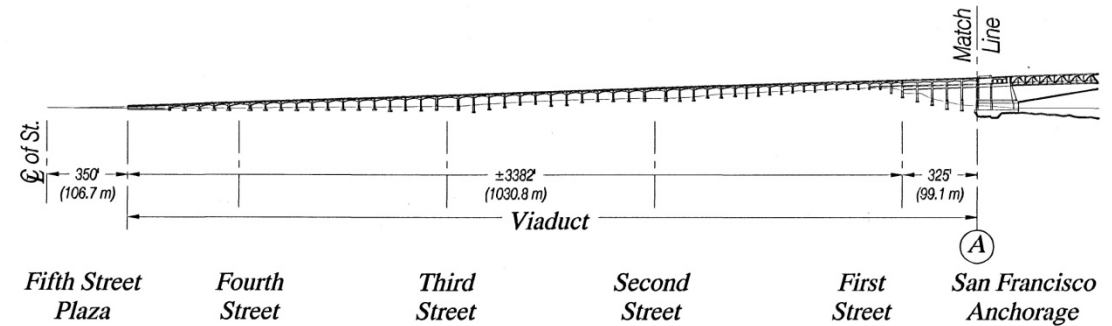


SURVEYING FOR THE BRIDGE



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.

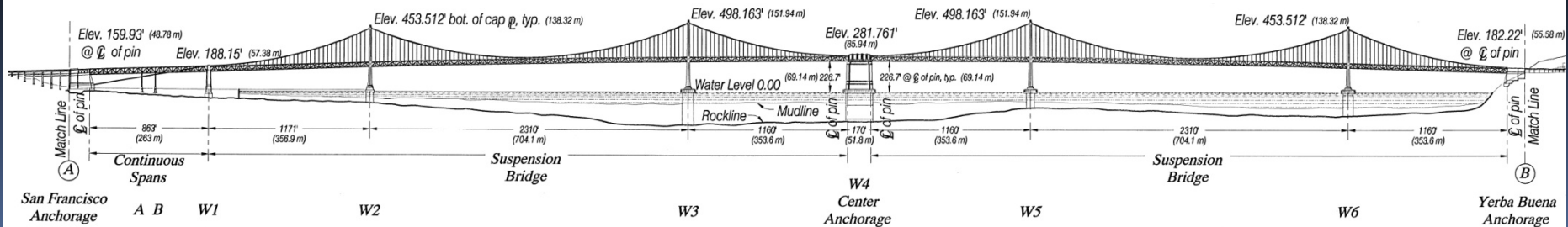


San Francisco Approach



West Bay Crossing

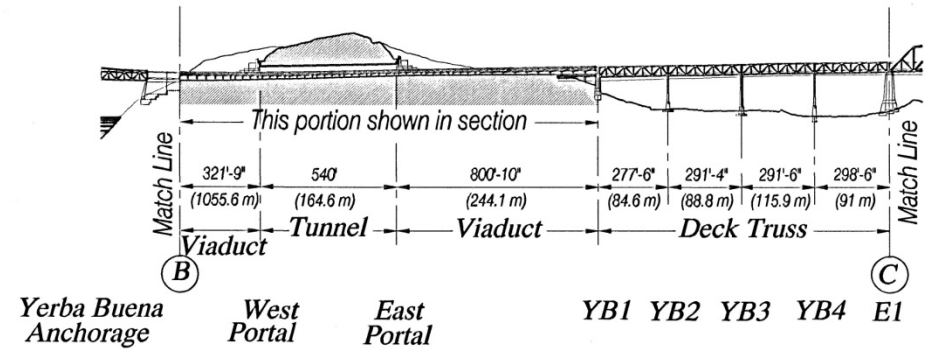
The West Bay Crossing consists of tandem 2,310 foot span suspension bridges connected by a massive center anchorage. The side spans are 1,160 feet long except at the west end of the western span which is 1,171 feet. The bridge originally contained an upper deck for automobiles and a lower deck for trucks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



West Bay Crossing

Yerba Buena Crossing

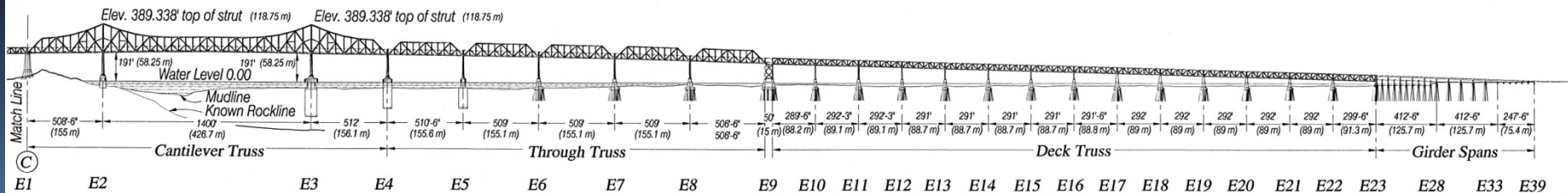
The Yerba Buena Crossing consists of a main tunnel with concrete portals, and viaducts linking both levels of traffic on the West Bay and East Bay Crossings. The tunnel is a tiled concrete vault supported by concrete sidewalls. A curved steel deck truss viaduct extends over the east side of the island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



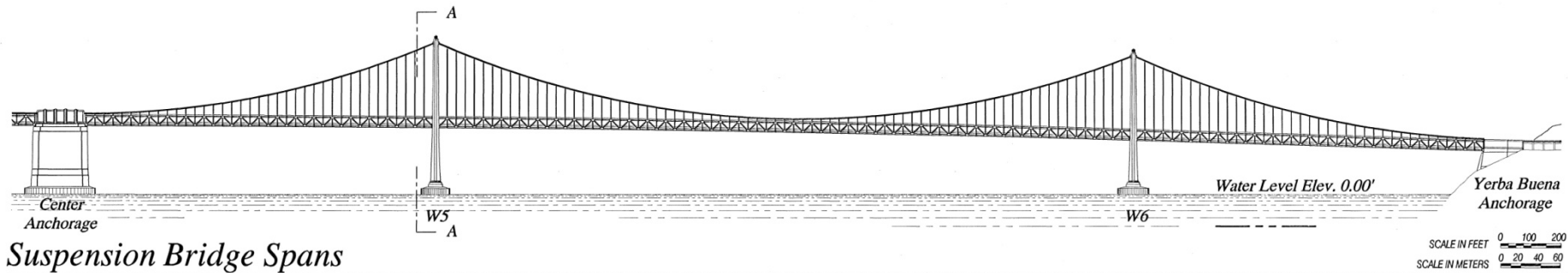


East Bay Crossing

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

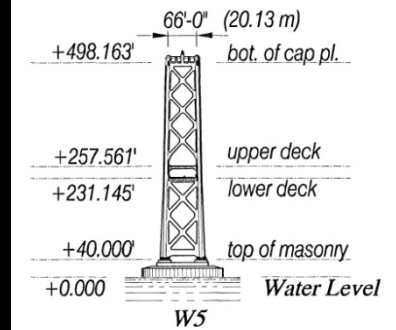


Suspension Bridge Spans

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

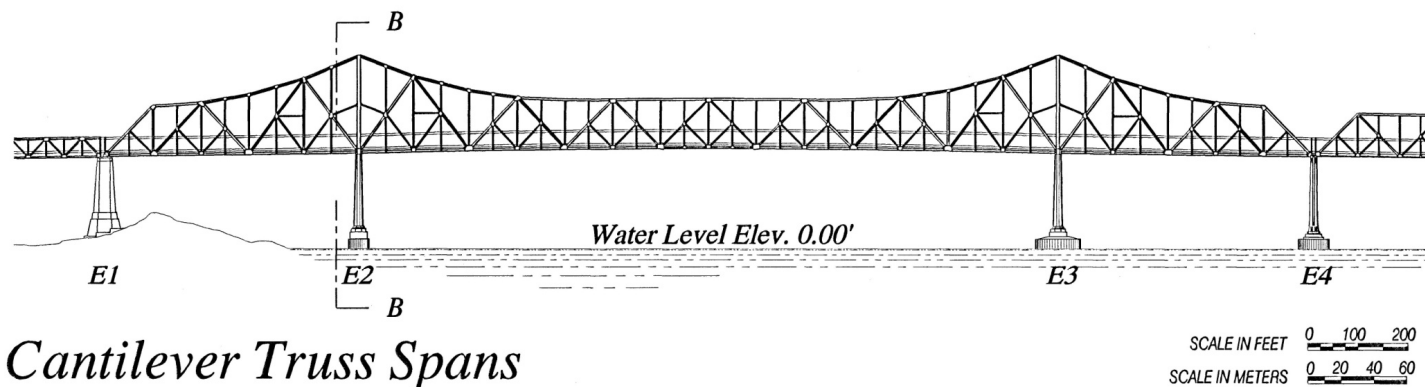
supported by the cables, which are in tension and the towers which are in compression. The deck systems are supported on floor beams which are anchored to the panel points of the truss.



Section A-A

Truss Bridges-General Notes

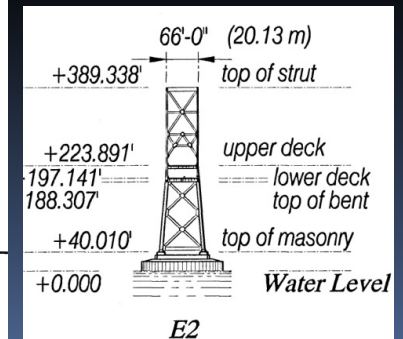
The Truss bridges consist of parallel trusses, 66 feet apart. Cross members and bracing tie the top and bottom chords together creating a box-like cross section. The trusses are composed of a combination of straight members arranged in a triangular pattern. They are connected so that the stresses in 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.



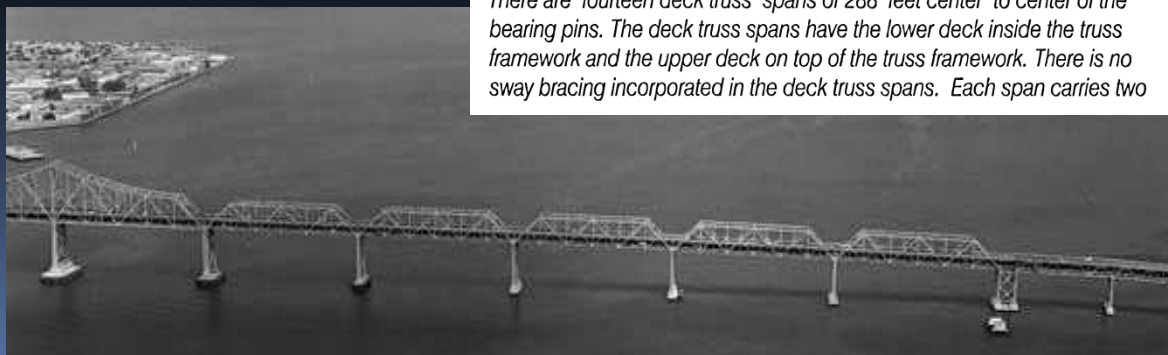
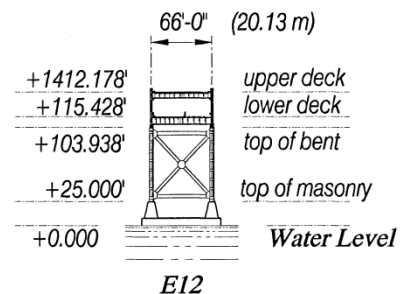
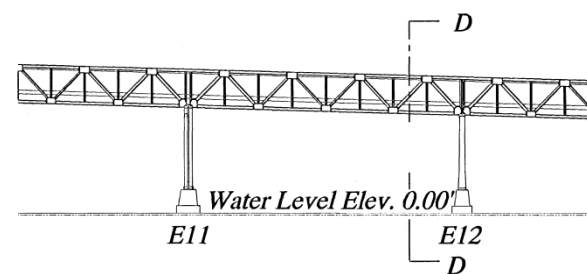
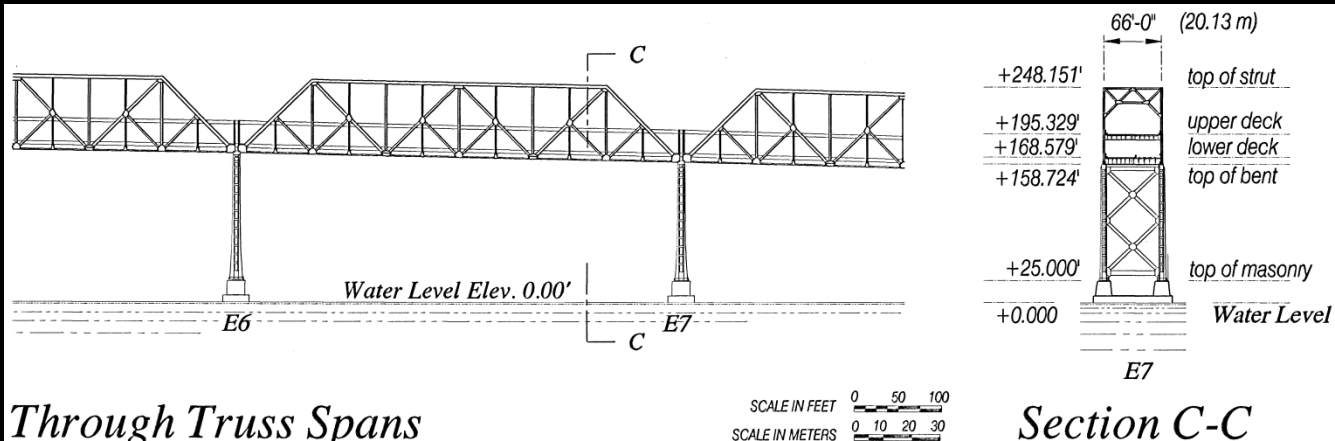
Cantilever Truss Spans

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.

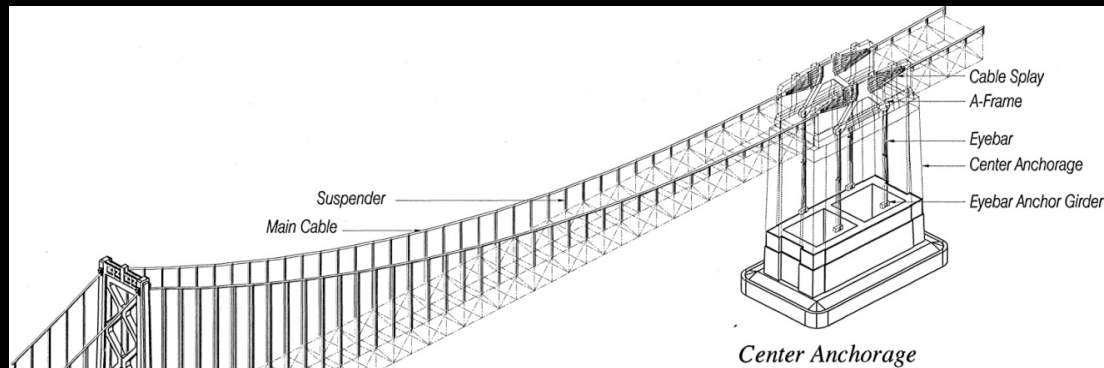


Section B-B



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.

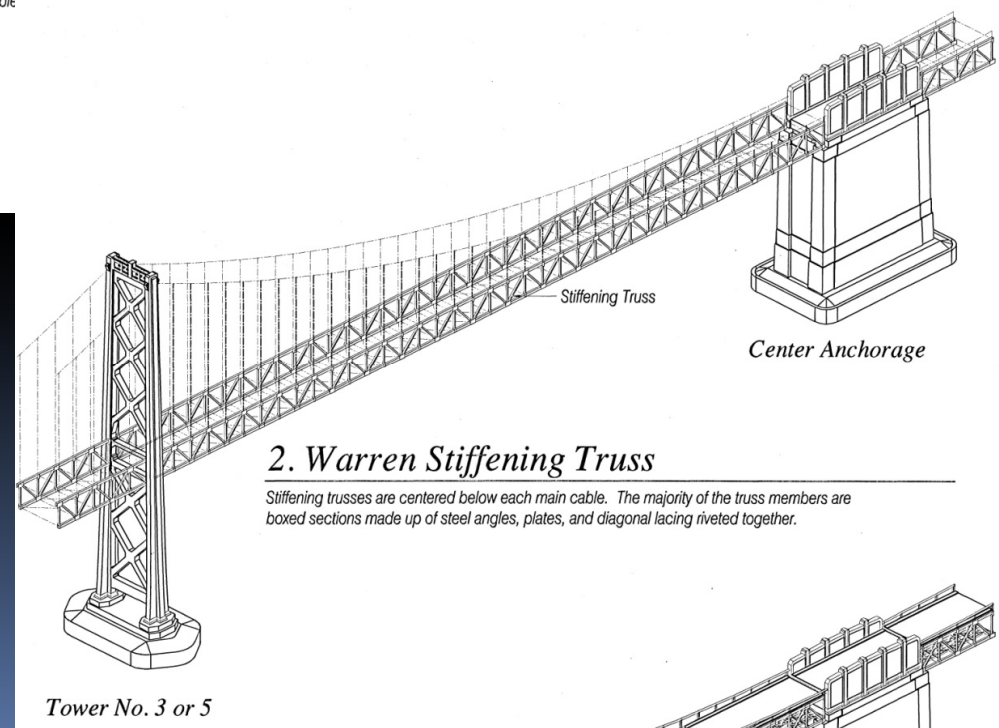
SUSPENSION BRIDGE STRUCTURAL SYSTEMS



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.

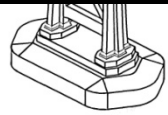
Tower No. 3 or 5



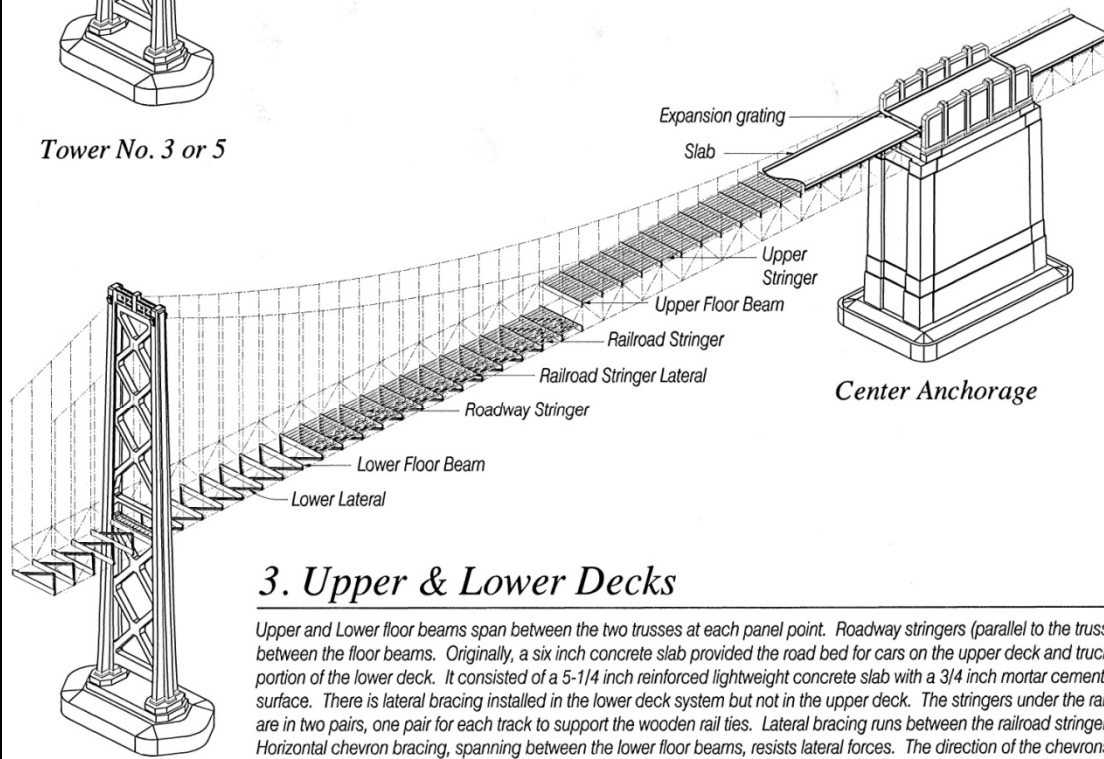
2. Warren Stiffening Truss

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.

Tower No. 3 or 5



Tower No. 3 or 5

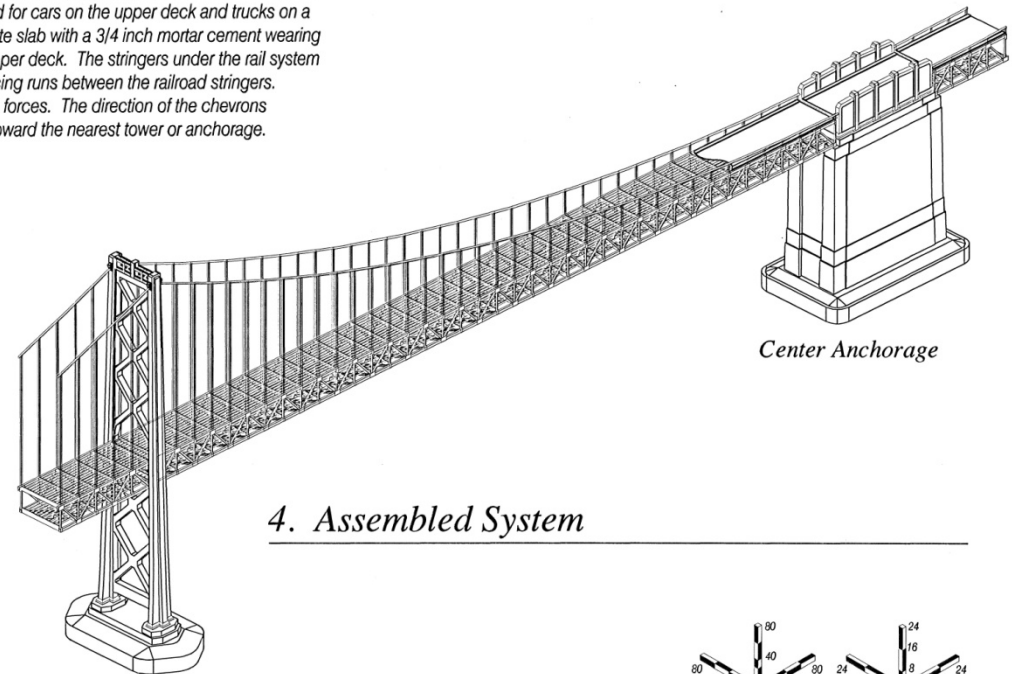


Center Anchorage

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.

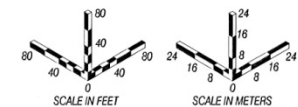
Tower No. 3 or 5



Center Anchorage

4. Assembled System

Tower No. 3 or 5



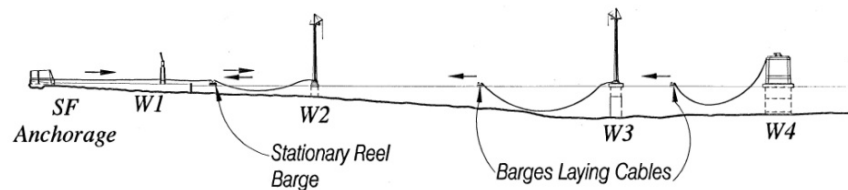
Cable Spinning Procedure

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.

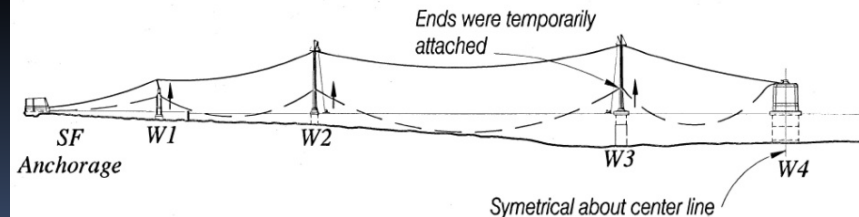
ONCE THE ANCHORAGES, PIERS, ROCKER ARMS AND TOWERS WERE COMPLETED, THE CABLE SPINNING COULD BE STARTED. THE FIRST STEP WAS TO INSTALL A SYSTEM OF CATWALKS, A GANTRY SYSTEM TO SUPPORT THE TRAMWAY WIRE ROPES, AND STORM CABLES. TWO ROPES WERE REQUIRED ON EACH EDGE OF EACH CATWALK. THERE WERE TWO CATWALKS 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.

SUSPENSION BRIDGE CONSTRUCTION



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.



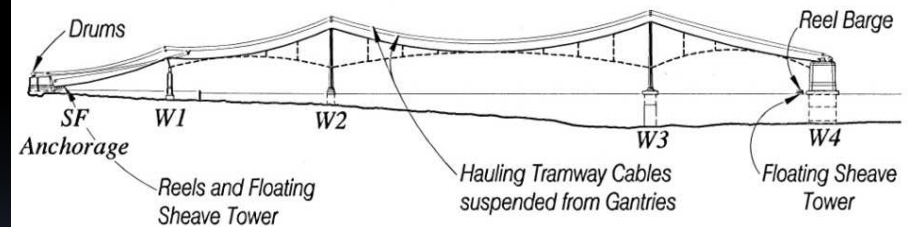
Stage 2: Raising Catwalk Cables

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.



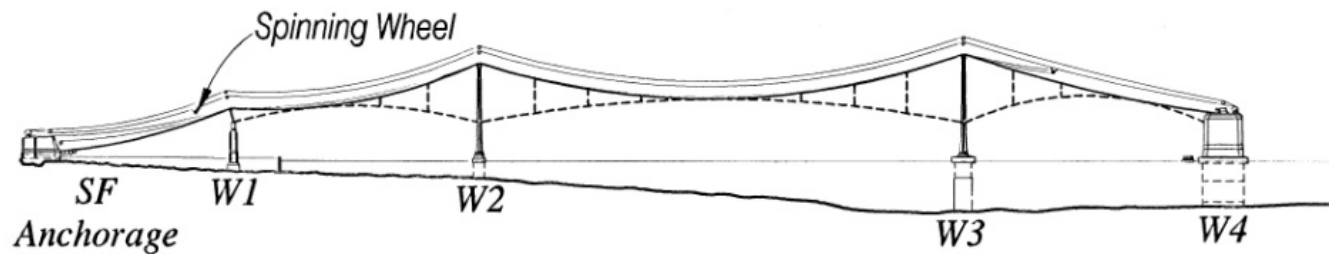
Stage 3: Installing Catwalk, Gantries and Storm Cables

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

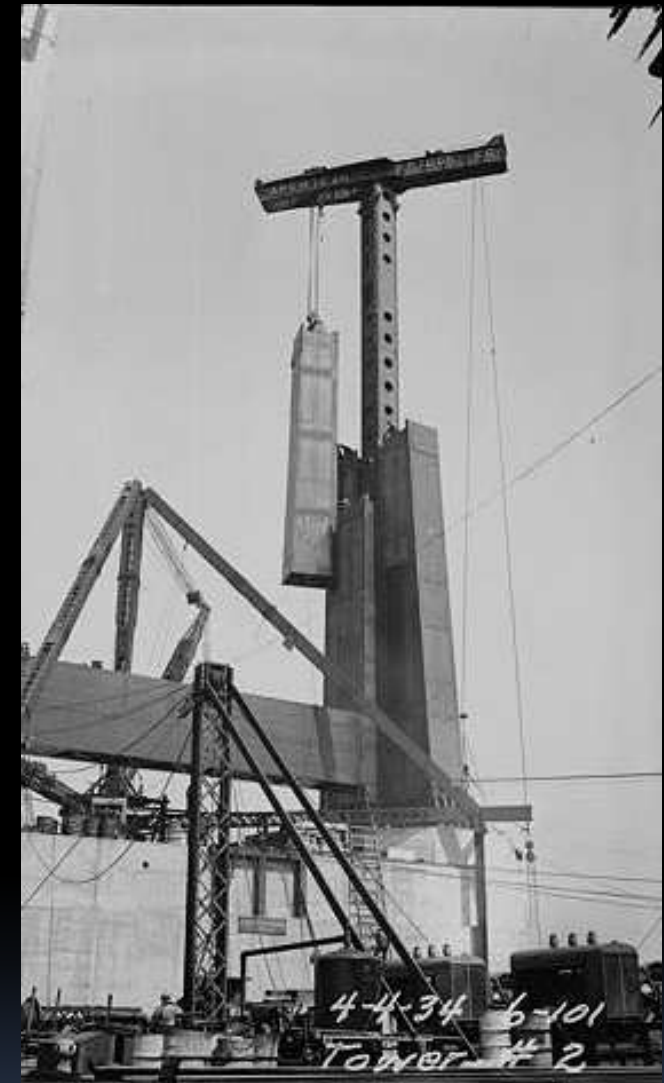
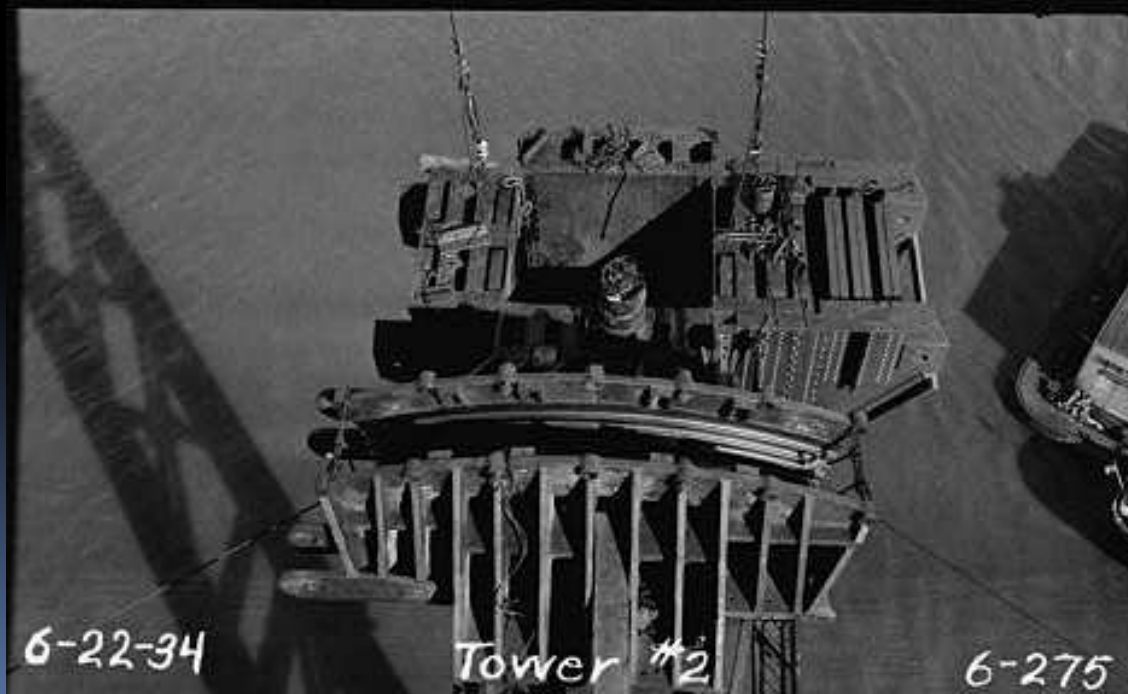
THE TRAMWAY CABLES AND WHEELS USED TO LAY THE WIRES OF THE MAIN CABLE WERE INSTALLED AND USED TO TRANSPORT THE WOODEN GALLOWES FRAMES DOWN FROM THE TOWER AND INTO POSITION ALONG THE CATWALKS. THE GALLOWES HAD PROVISIONS TO LIFT THE WIRE GROUPINGS TO AND FROM TEMPORARY CABLE SPLAY CASTINGS ALONG THE CATWALK 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.



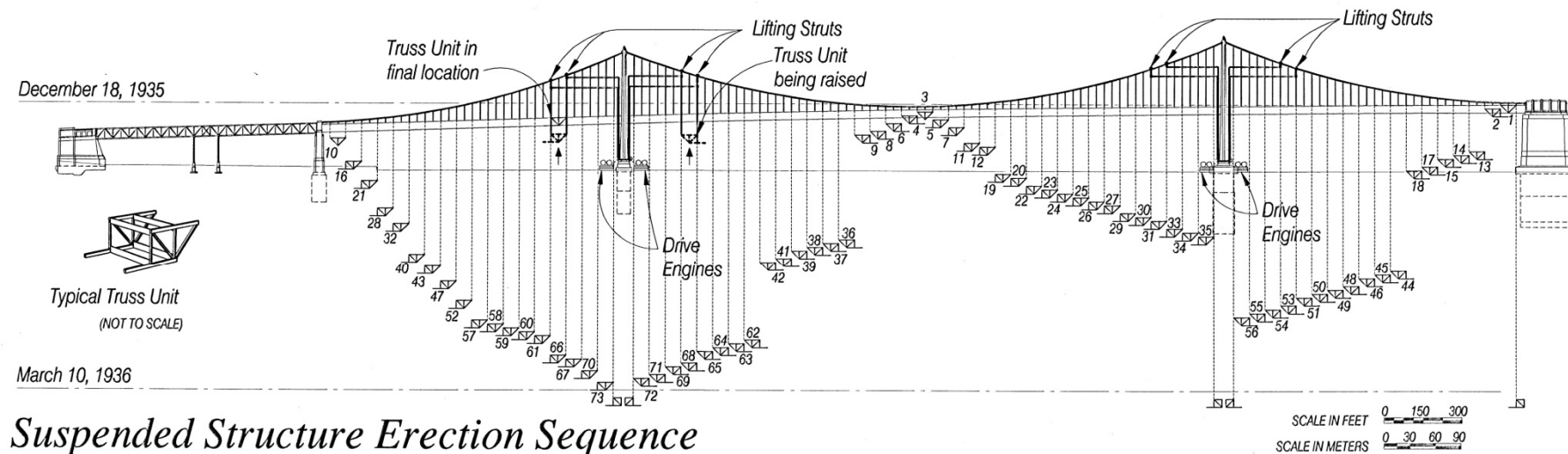
Stage 5: Spinning Wheels Arriving at Anchorages

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.





Tower and cable saddle
construction

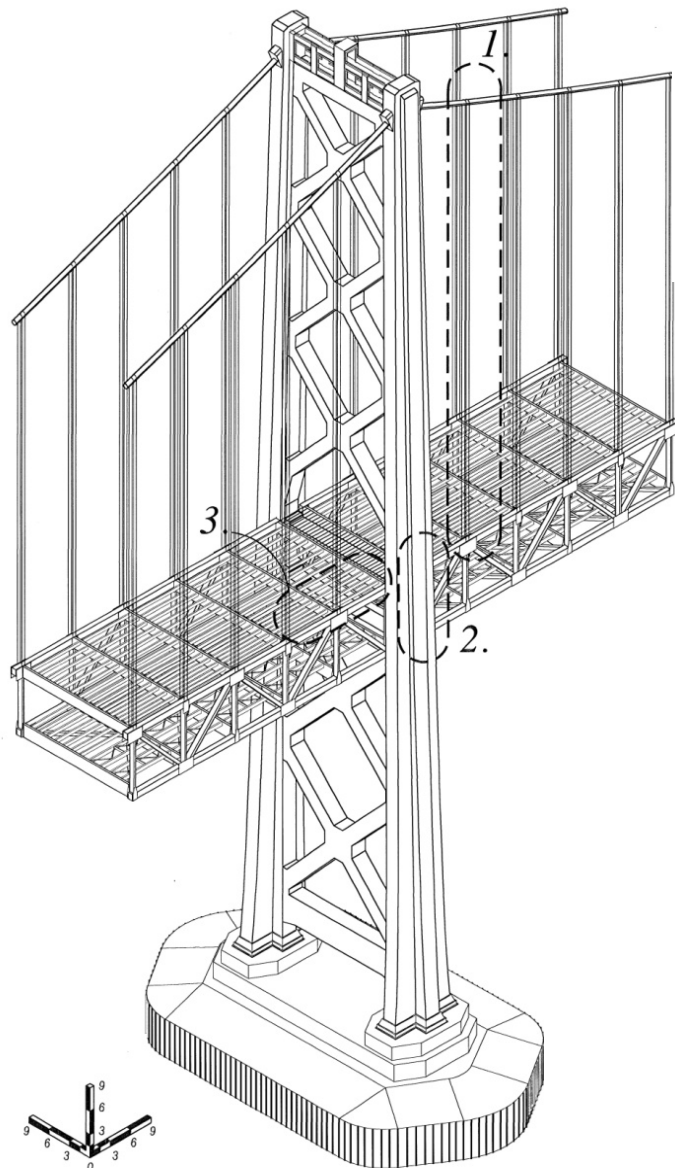


Suspended Structure Erection Sequence

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.





1. Truss Suspension

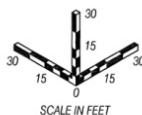
At each suspender location (Inset 1), the wires of the cable are clamped together with a cast steel cable band that is bolted together around the cable. Friction due to the clamping force prevents the cable bands from slipping down the cables. Grooves in the cable band provide support for the suspender 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.

SUSPENSION BRIDGE DETAILS

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.

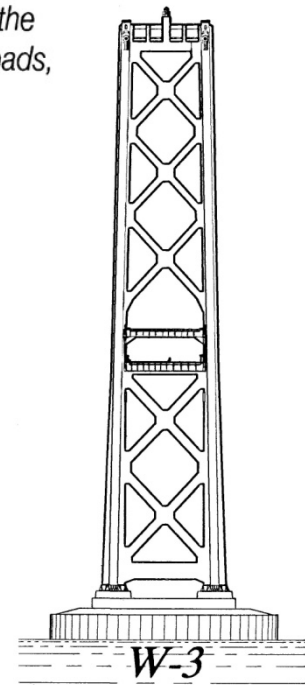
These top and bottom connections are pivoted, using bearing pins that are oriented in the direction of the transverse axis of the bridge. The rocker arms support the weight of the last panel of each truss, as compression links. Under imposed loads and environmental conditions - wind, earthquake, traffic, 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.

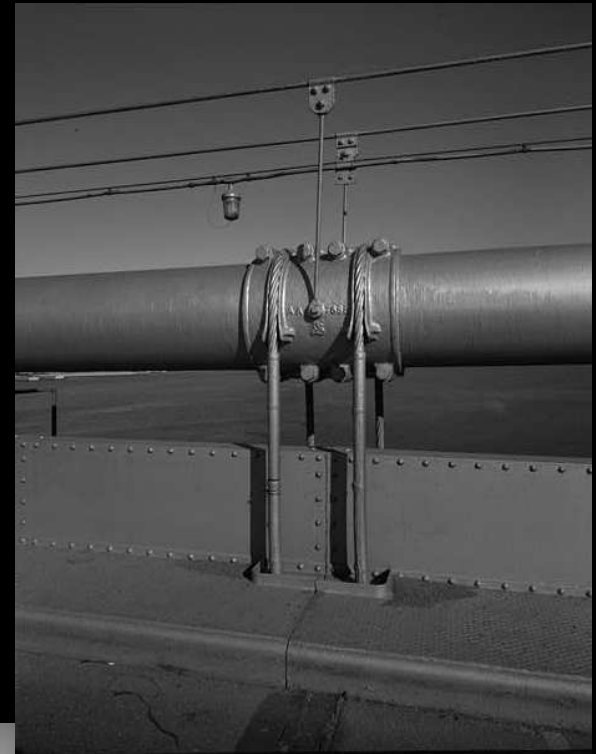


Suspension Tower Details

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.

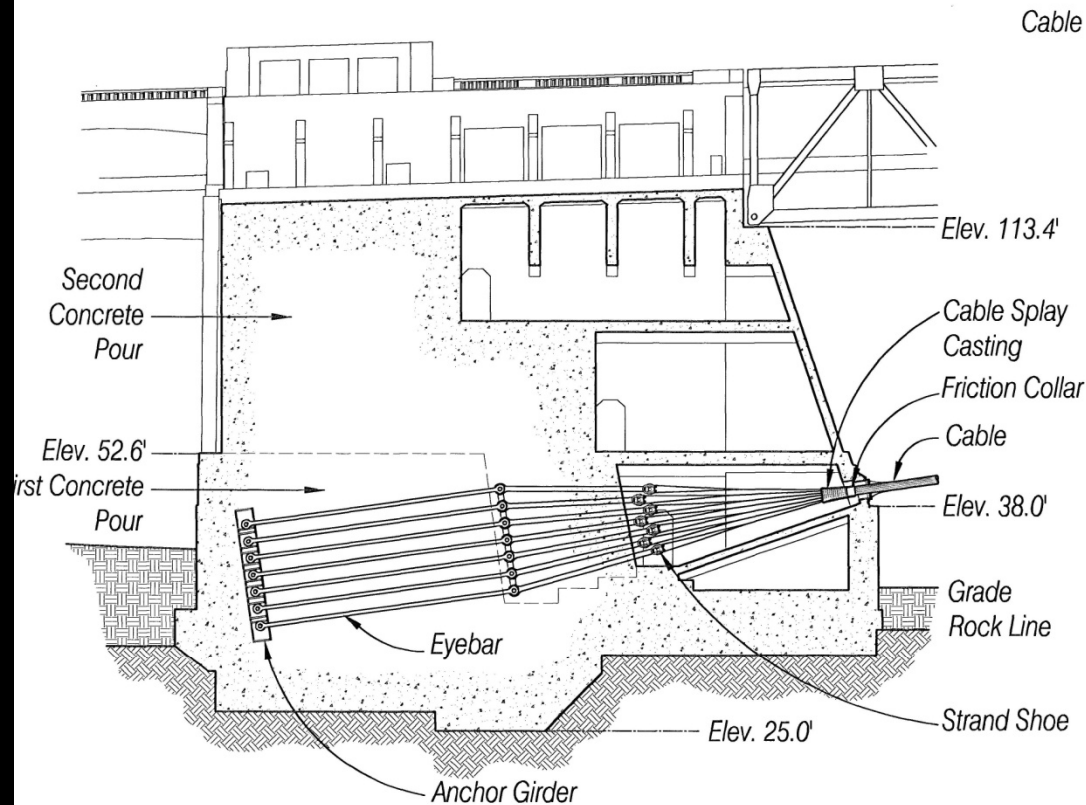
Suspension Tower



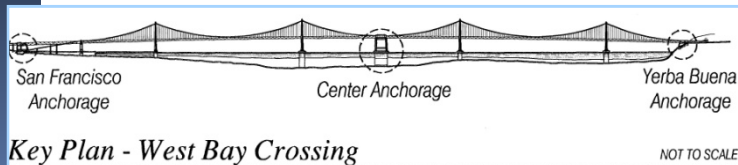
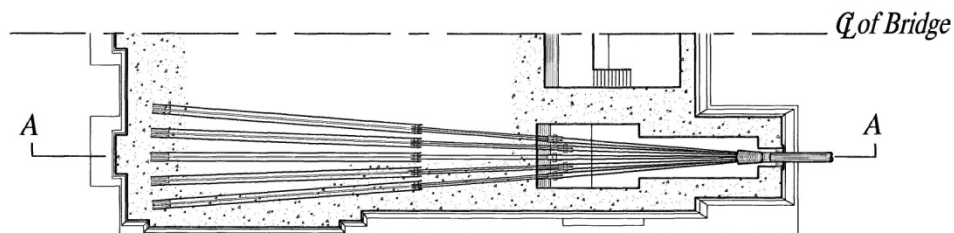




SAN FRANCISCO ANCHORAGE

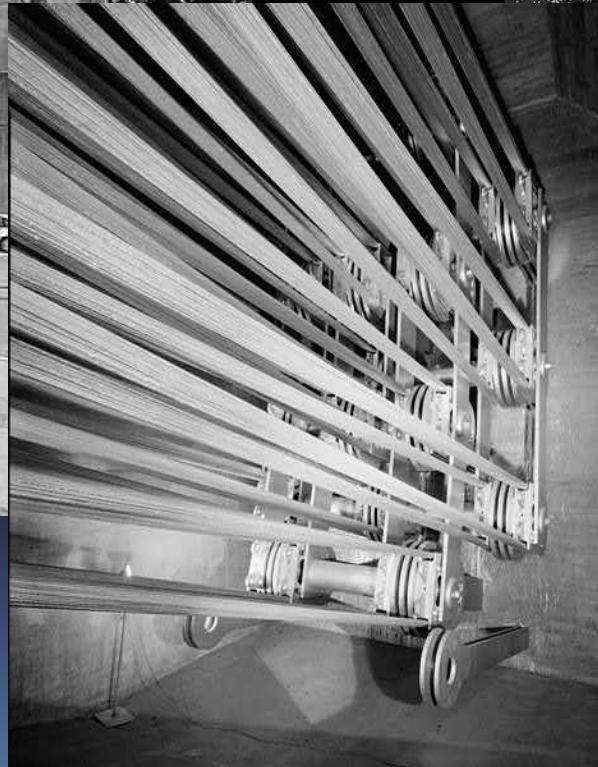
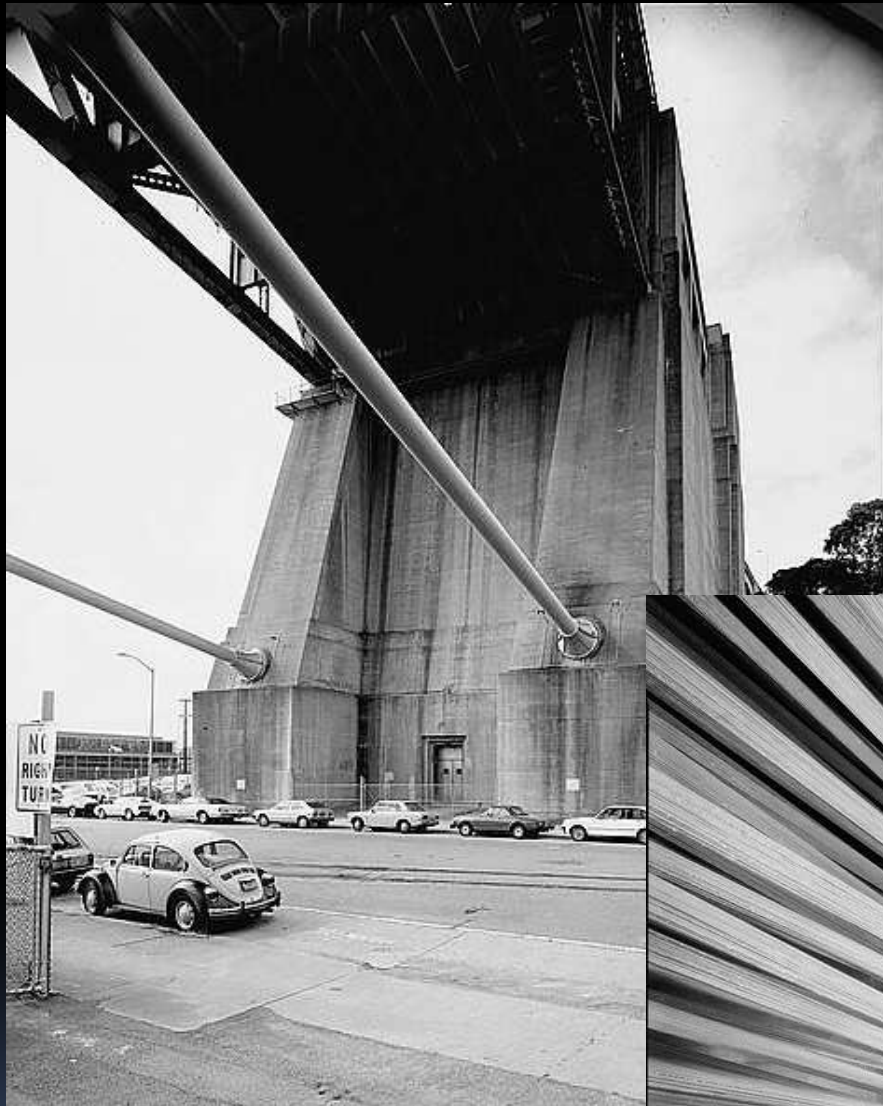


Section A-A



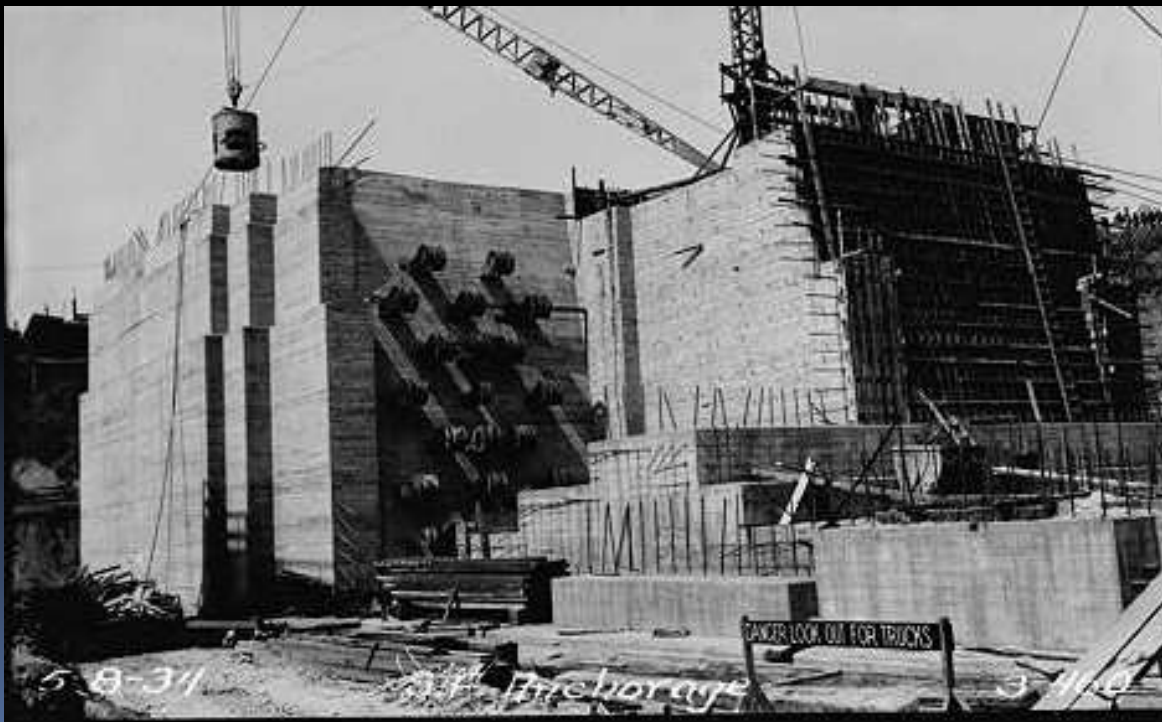
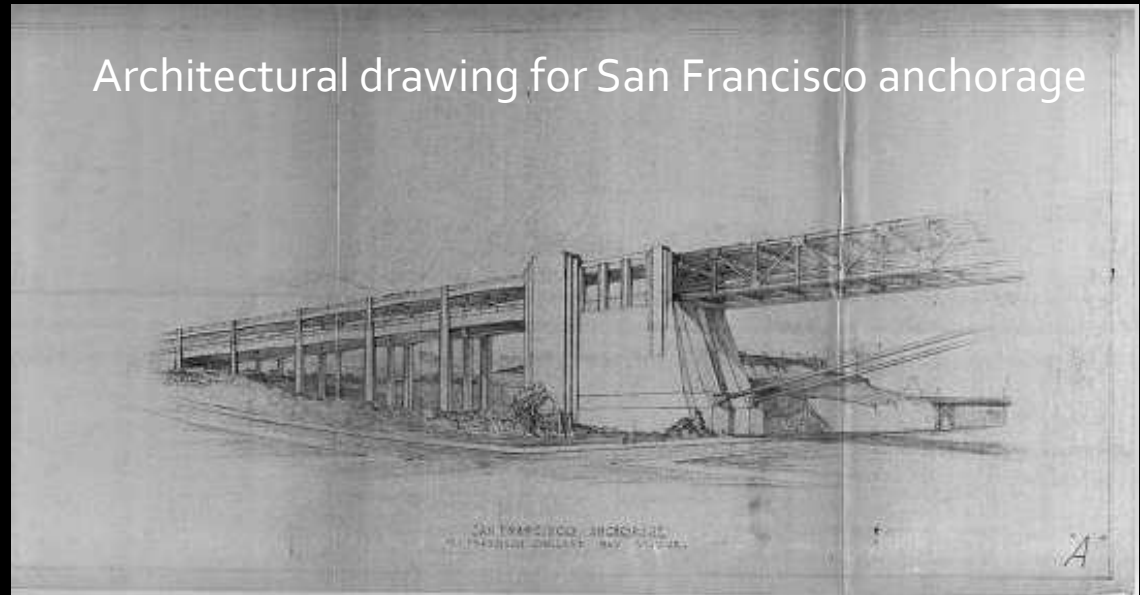
SCALE IN FEET 0 15 30
SCALE IN METERS 0 3 6 9

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.



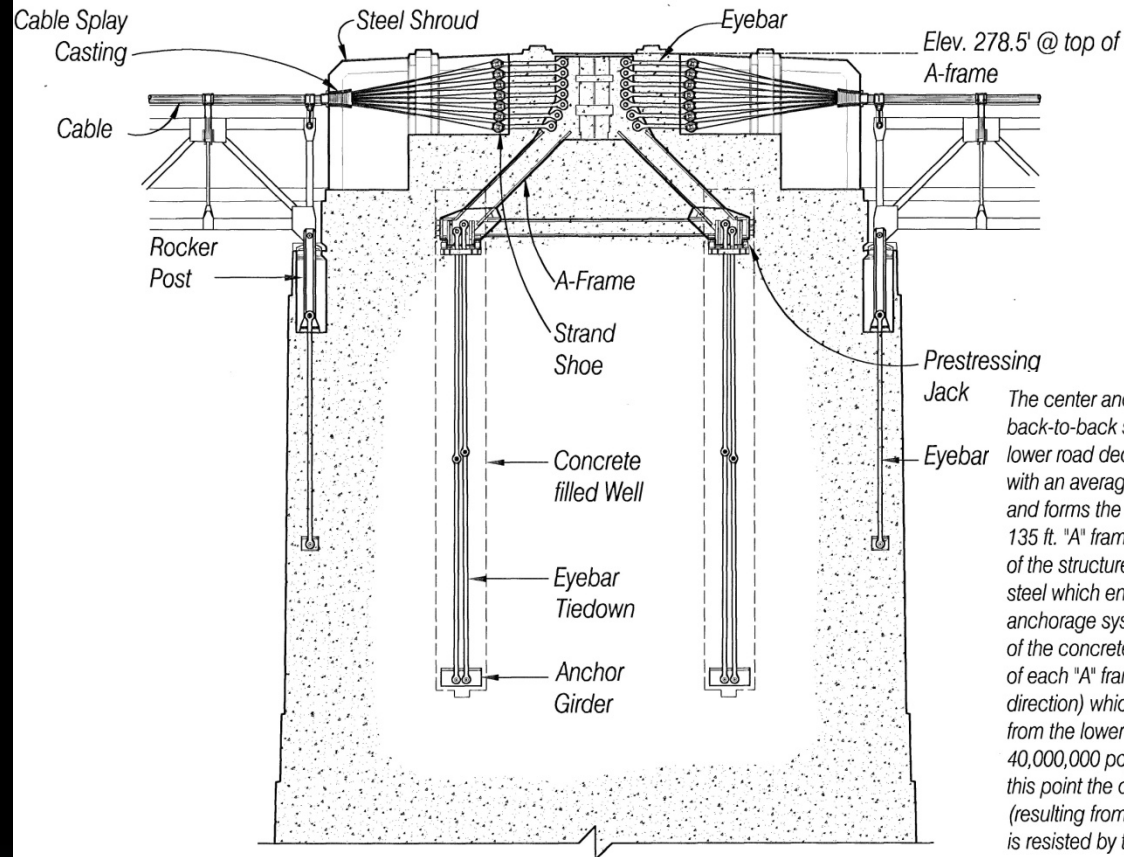
Inside the San Francisco anchorage

Architectural drawing for San Francisco anchorage



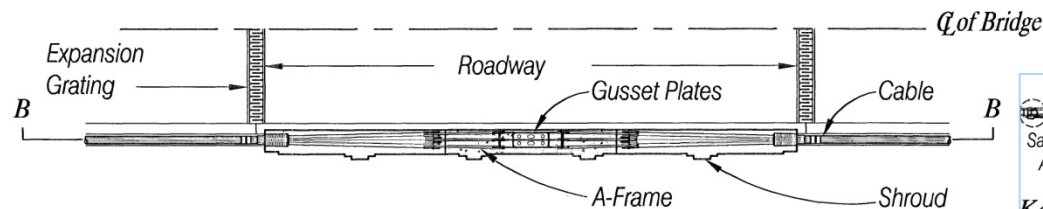
San Francisco anchorage
under construction

CENTER ANCHORAGE



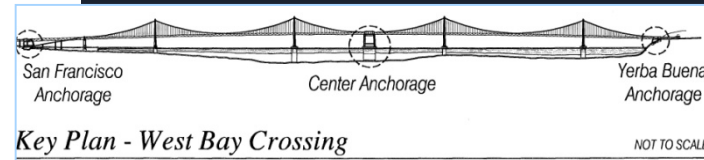
Section B-B

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 eyebars 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 bridge. 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.



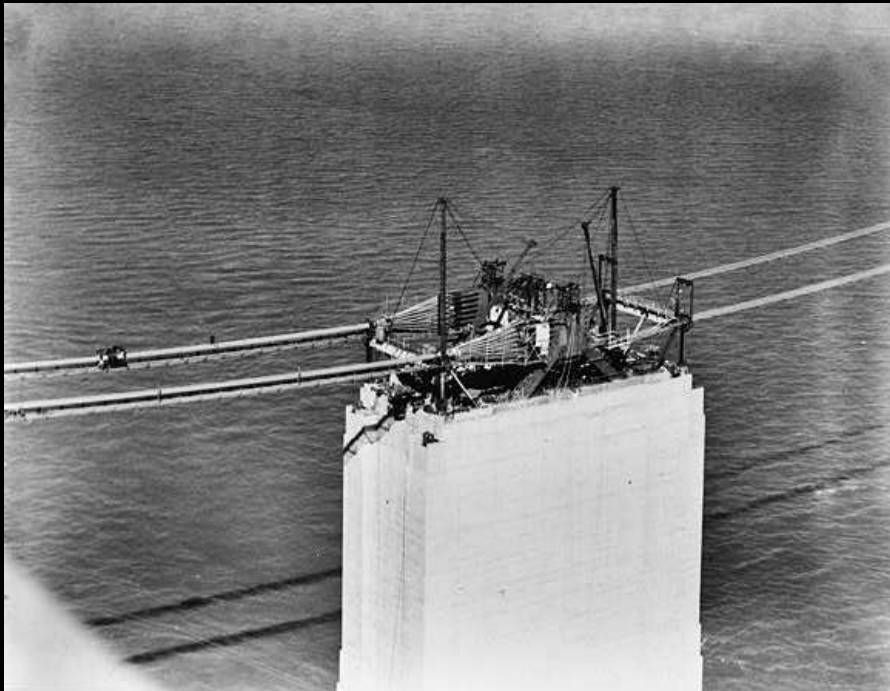
Half Plan @ Elev. 278.5'
Center Anchorage

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





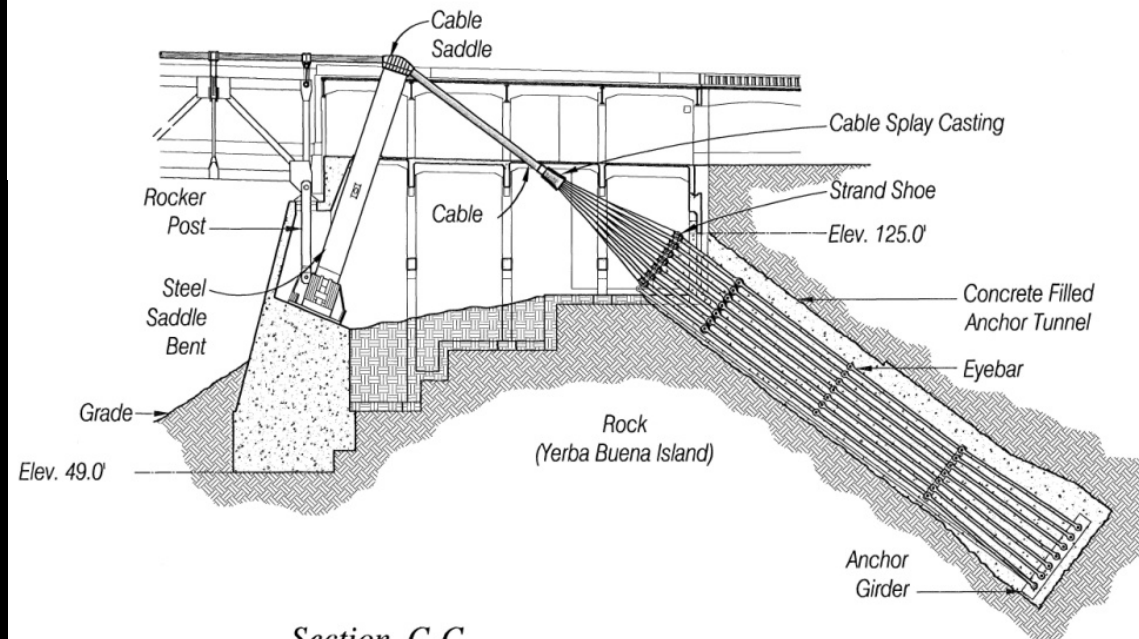
Inside the center anchorage



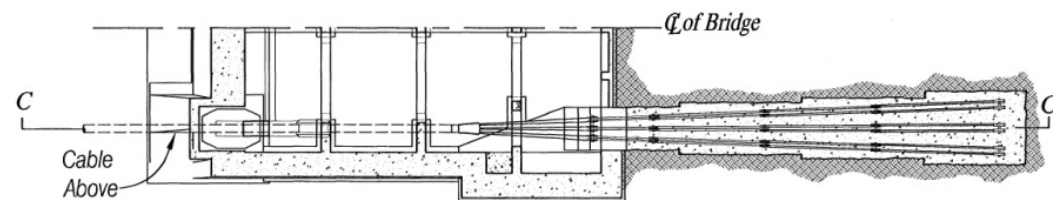
Center anchorage
under construction



YERBA BUENA ANCHORAGE



Section C-C



Half Plan @ Elev. 125.0'

Yerba Buena Anchorage



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

Cable saddle casting



Inside the Yerba Buena anchorage



Rocker arm



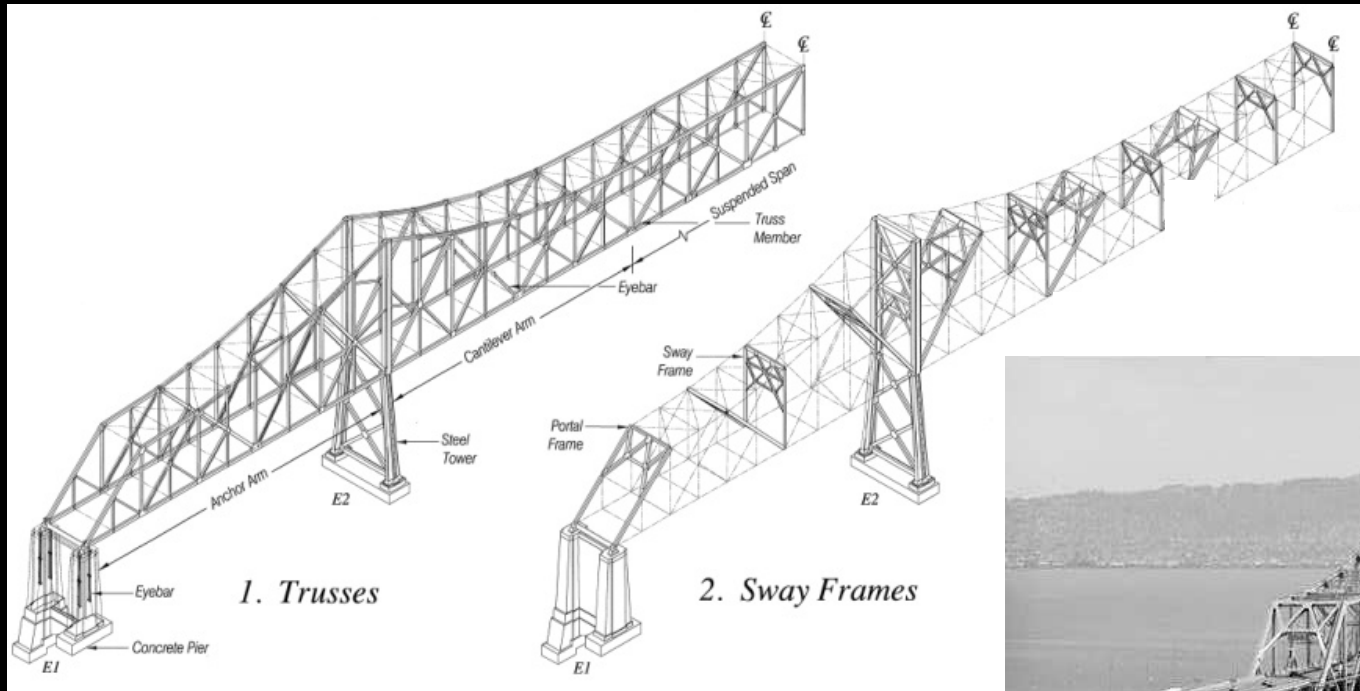
Strand shoes and eye bars

Construction of the Yerba Buena anchorage



YERBA BUENA TUNNEL CONSTRUCTION





CANTILEVER TRUSS

1. Trusses

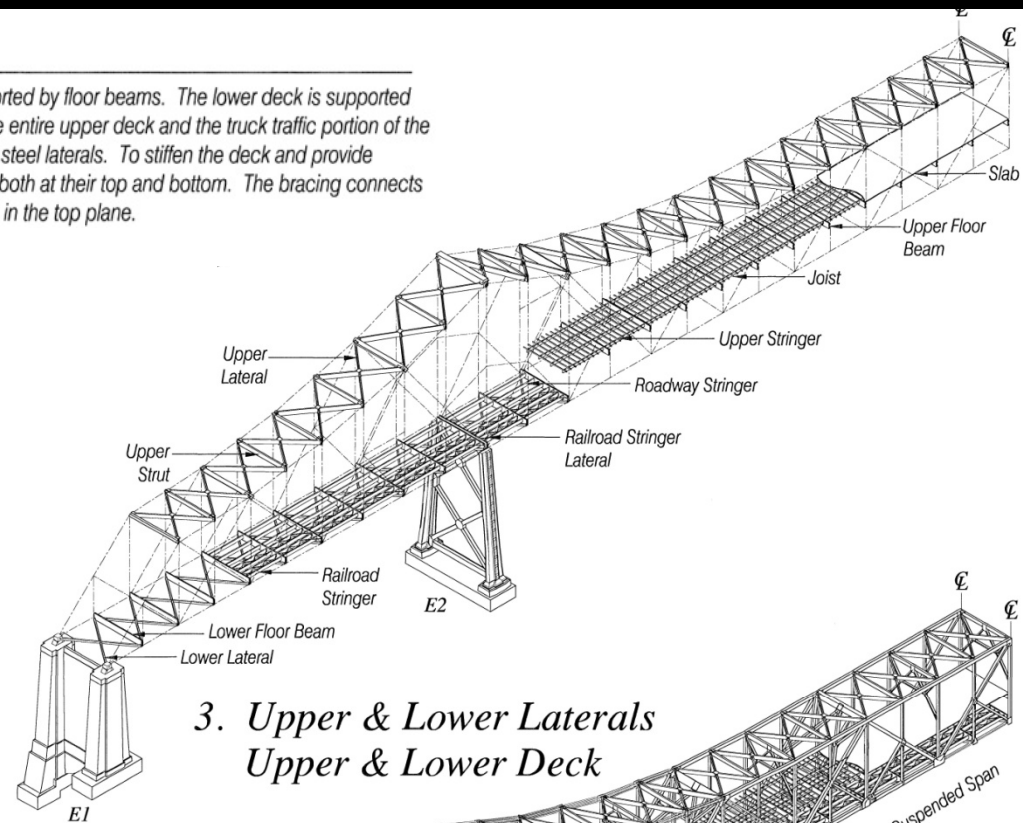
The cantilever trusses of the East Bay Crossing comprise a number of different member types designed and built to resist various forces. The connections between these members are designed to transfer forces between the members and to provide freedom from extraneous restraints that cause undesirable secondary 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

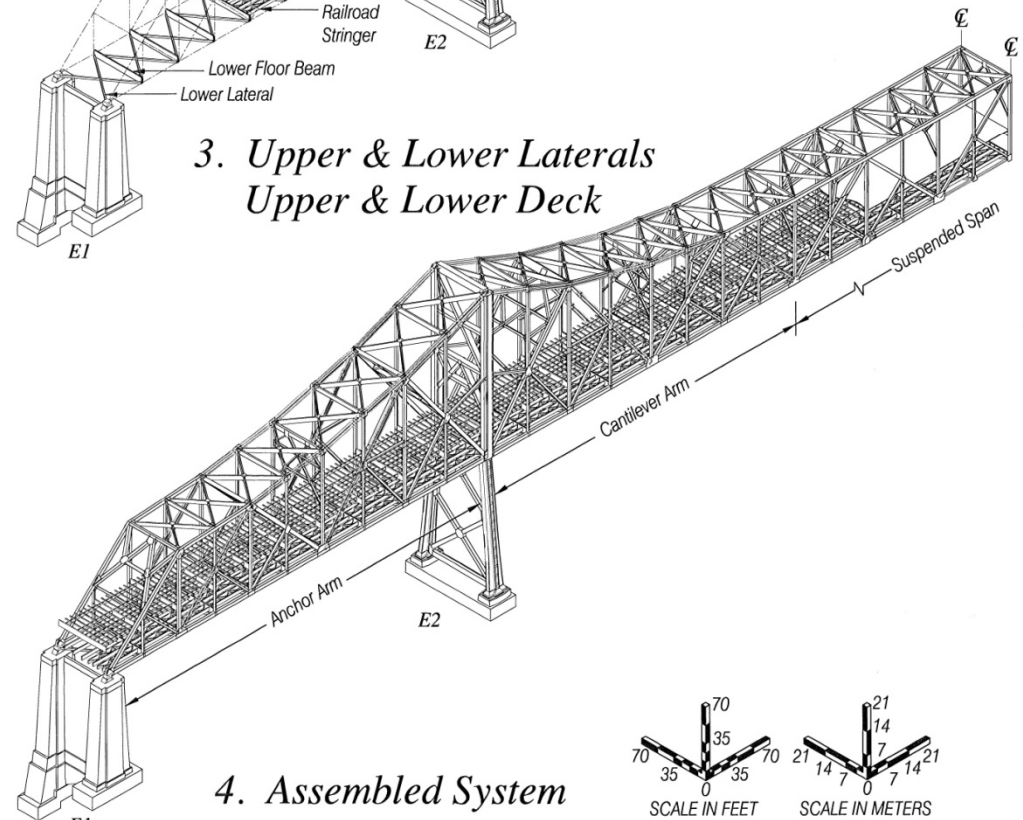
The cantilever truss is stabilized against lateral forces with sway frames. These braces, located at the key panel points, span the trusses high above the upper deck traffic.

3. Upper and Lower Decks, Upper and Lower Laterals

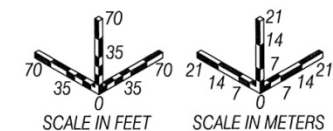
The upper roadway is supported by a system of joists on top of stringers, which in turn are supported by floor beams. The lower deck is supported only by a system of stringers on top of floor beams. A 6 1/2 in. reinforced concrete slab covers the entire upper deck and the truck traffic portion of the 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.

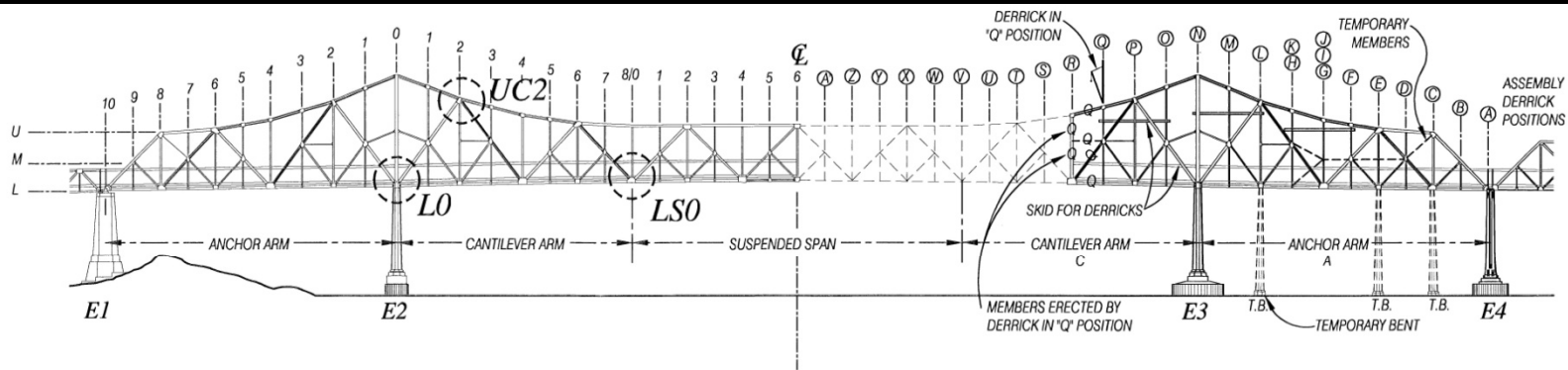


3. Upper & Lower Laterals Upper & Lower Deck



4. Assembled System





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.

Construction Sequence

Shown completed to derrick at position "Q".

SCALE IN FEET 0 750 1500
SCALE IN METERS 0 150 300 450



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.

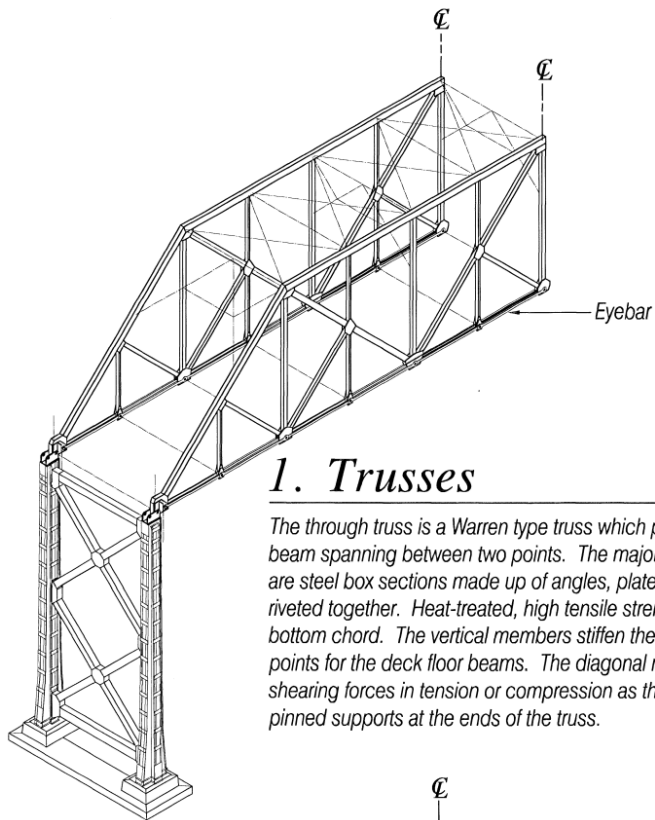
The erecting equipment consisted of two guy derricks mounted on one traveler, the Yerba Buena traveler with two booms in front and a lighter boom at the rear, and a jiniwink. The jiniwink was used for light work such as placing floor members, curbs, etc. The Yerba Buena Island traveler, used for constructing 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.



Construction of cantilever truss bridge

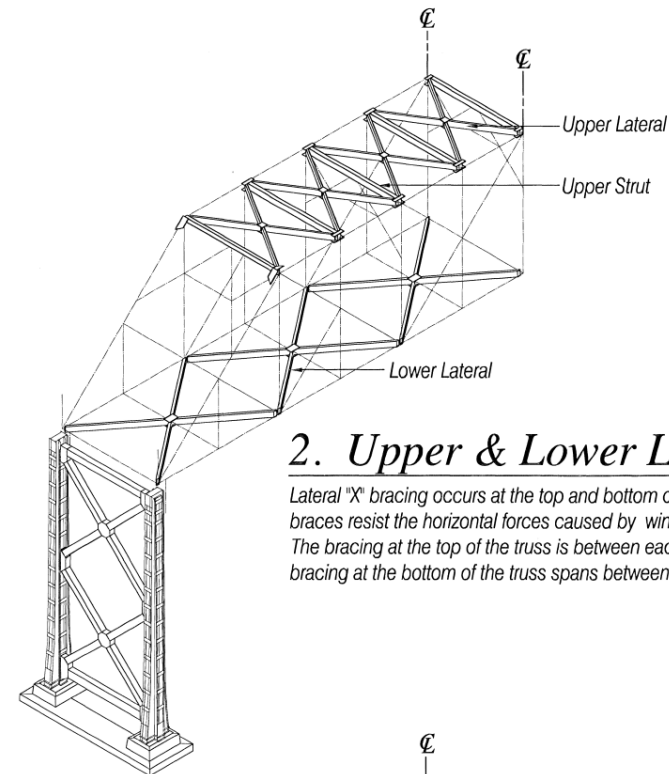


THROUGH TRUSS CONSTRUCTION



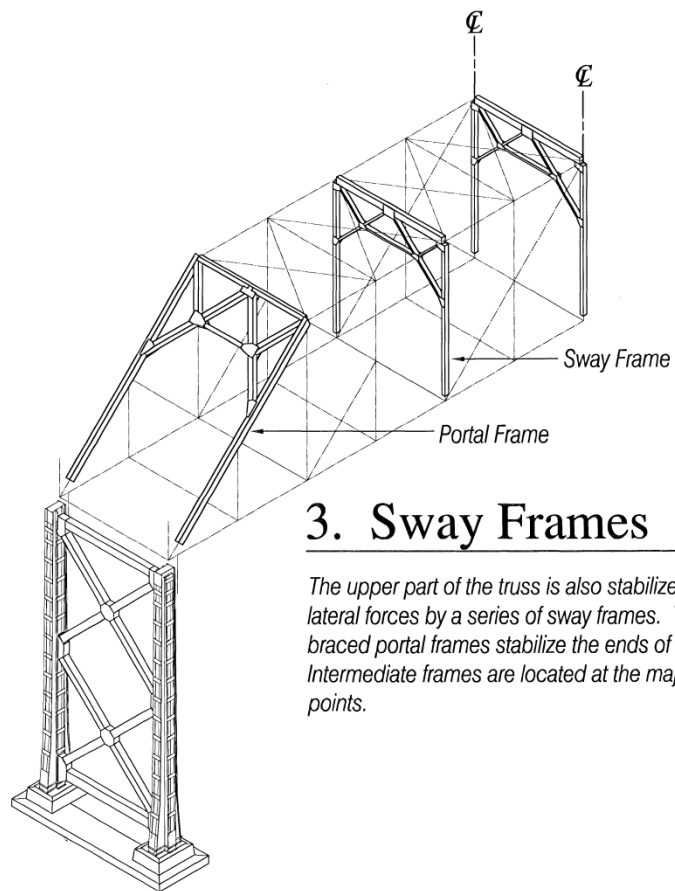
1. Trusses

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.



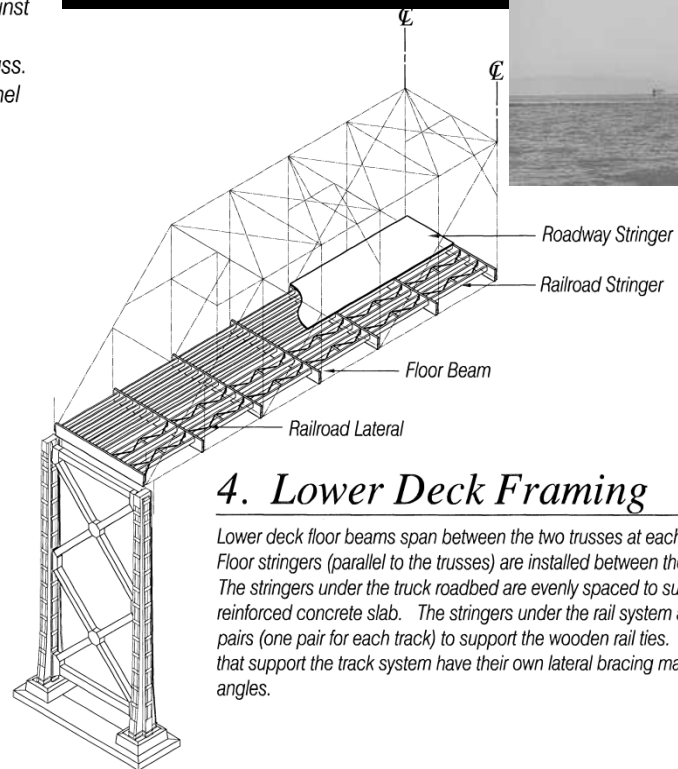
2. Upper & Lower Laterals

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.



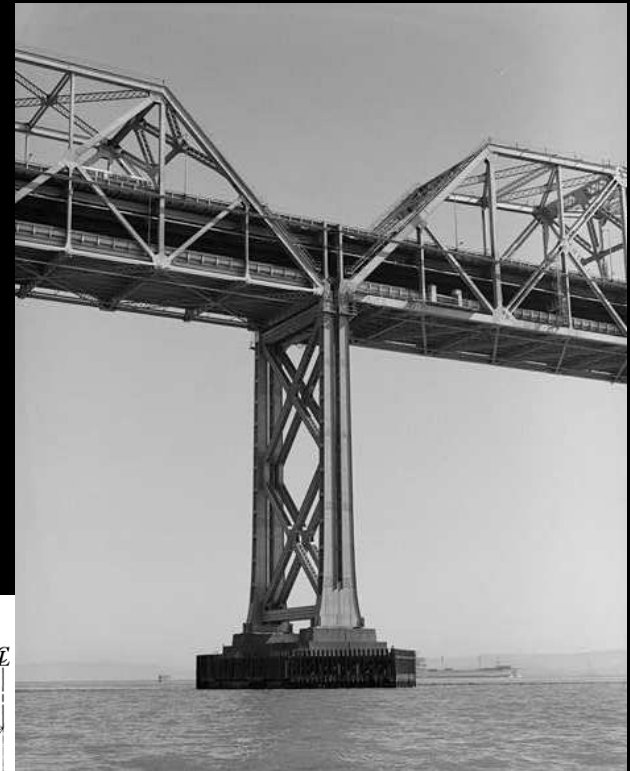
3. Sway Frames

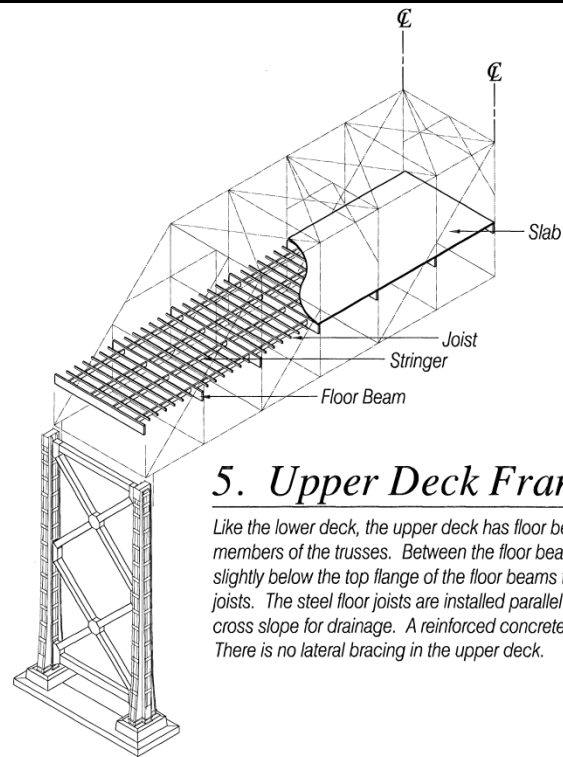
The upper part of the truss is also stabilized against lateral forces by a series of sway frames. These braced portal frames stabilize the ends of the truss. Intermediate frames are located at the major panel points.



4. Lower Deck Framing

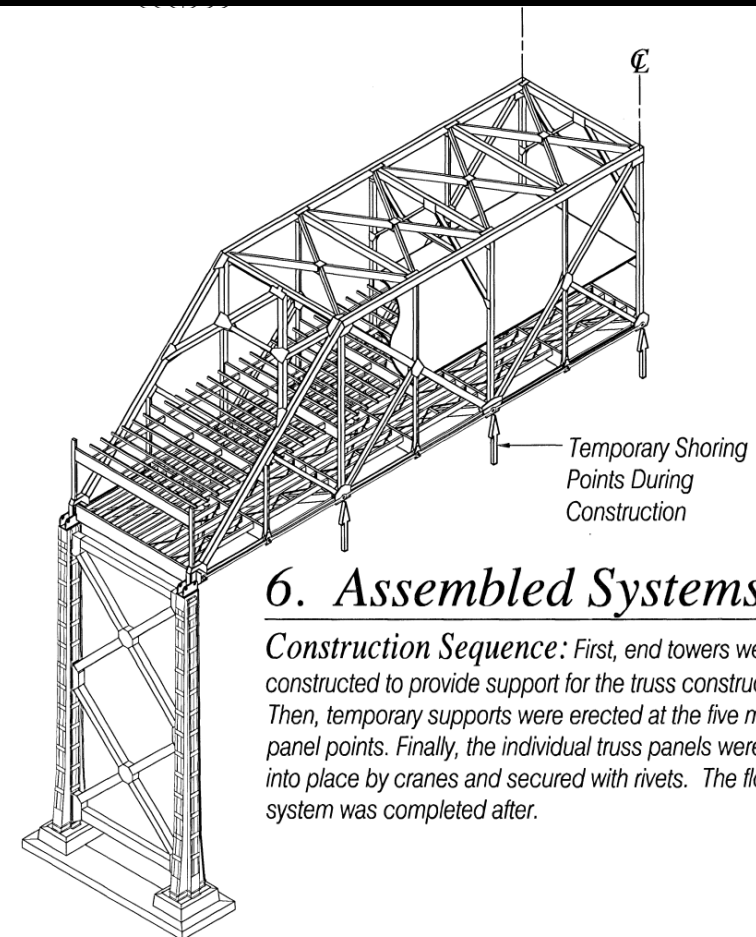
Lower deck floor beams span between the two trusses at each panel point. Floor stringers (parallel to the trusses) are installed between the floor beams. The stringers under the truck roadbed are evenly spaced to support a 6-1/2 in. reinforced concrete slab. The stringers under the rail system are installed 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.



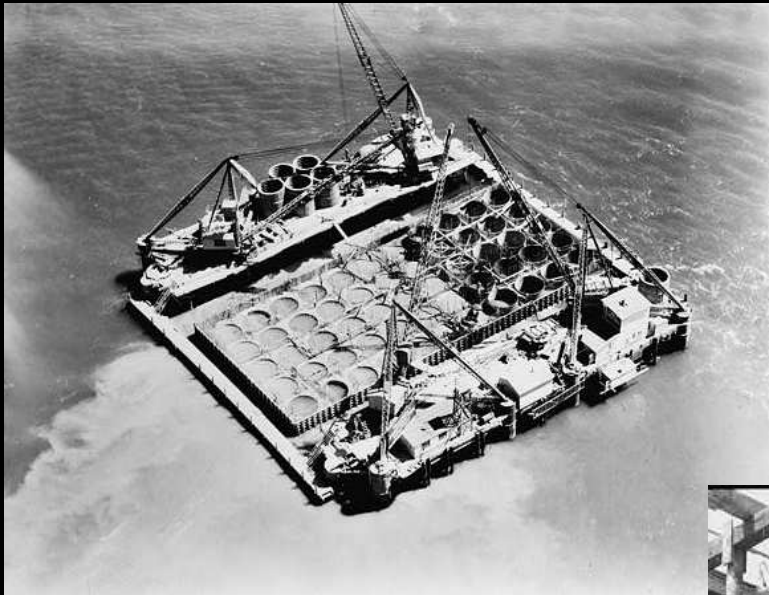


LOWER DECK CONSTRUCTION

When the bridge opened in 1936, the lower deck was for truck traffic and trains. The bridge was reconfigured to carry eastbound traffic on the lower level in 1958.



CAISSON CONSTRUCTION



Caisson being excavated
with domes in place



Bottom of cofferdam at Pier E-9
after pile driving complete



Under construction, July 1935



Bridge complete, November 1936



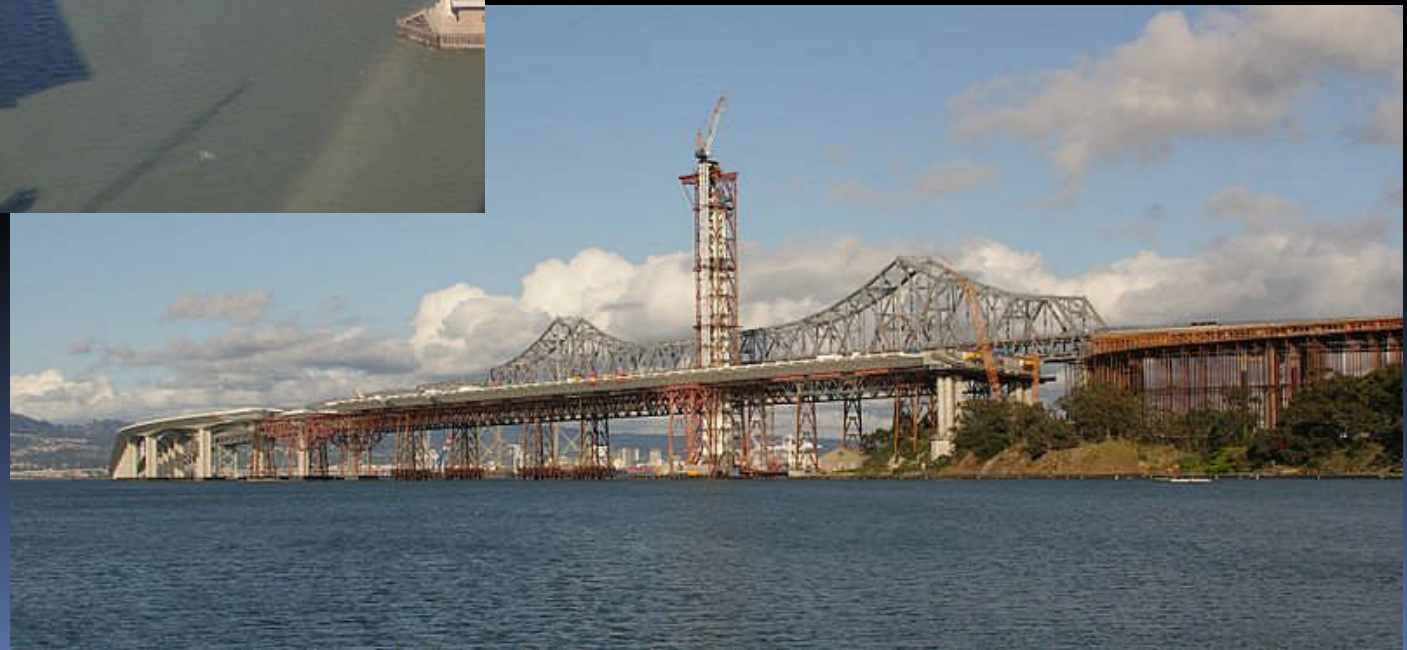
San Francisco Bay Bridge, 2006



Damaged by the 7.1 magnitude Loma Prieta earthquake in 1989, the eastern span of the Bay Bridge is being rebuilt ...



... with completion possibly as soon as 2013.
Follow the new bridge construction online at:
www.baybridgeinfo.org



NOTE:

Not all technical drawings were used in this presentation, specifically: Viaducts, West Span Foundation System, Anchorage and Cabling Details, Cantilever Truss Details, Deck Truss, East Span Foundation, Bridge Railway, and Bridge Reconstruction.

You can download all of the drawings in single pdf document here:

www.MavensManor.com/HAER/SFOBB.pdf

You can read the narrative on file in pdf form at:

<http://www.historicbridges.org/california/baybridge/ca1352.pdf>

To view the entire record online at the Library of Congress, visit:

<http://www.loc.gov/pictures/item/CA1352/>

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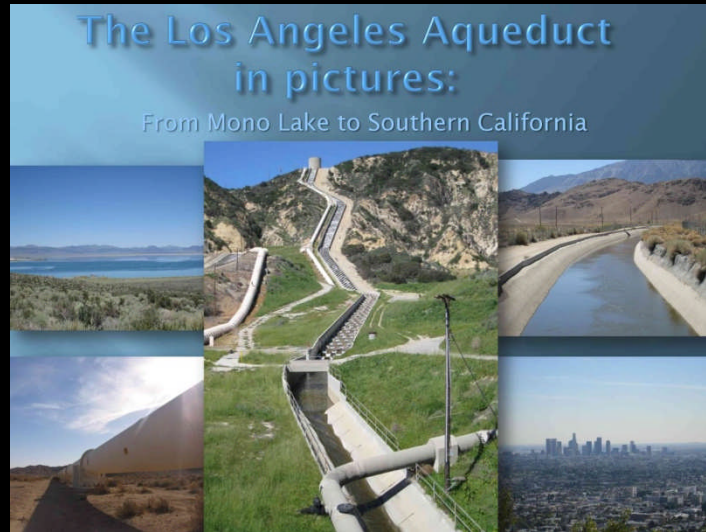
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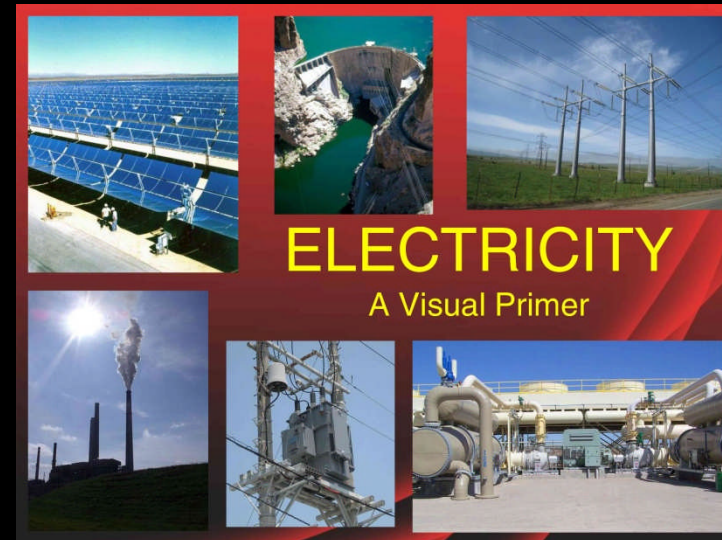
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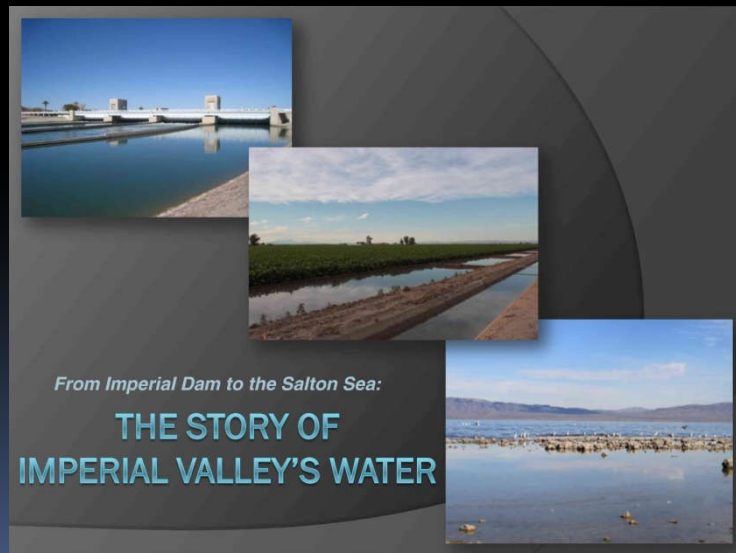
Also available online



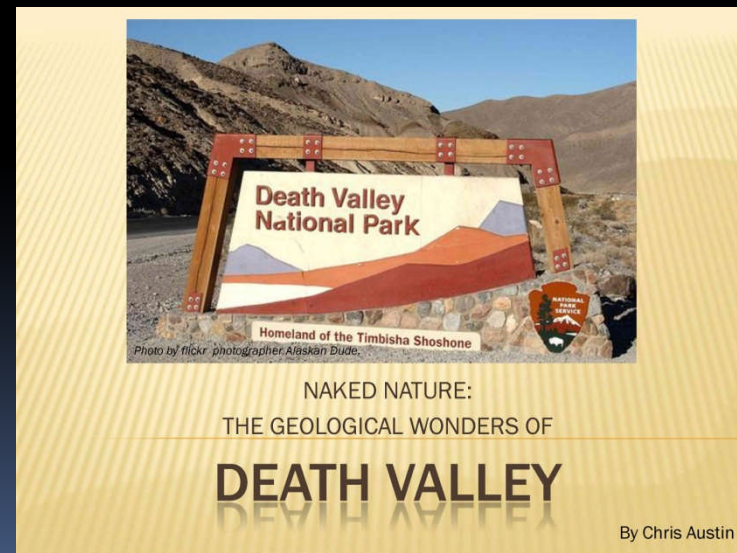
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