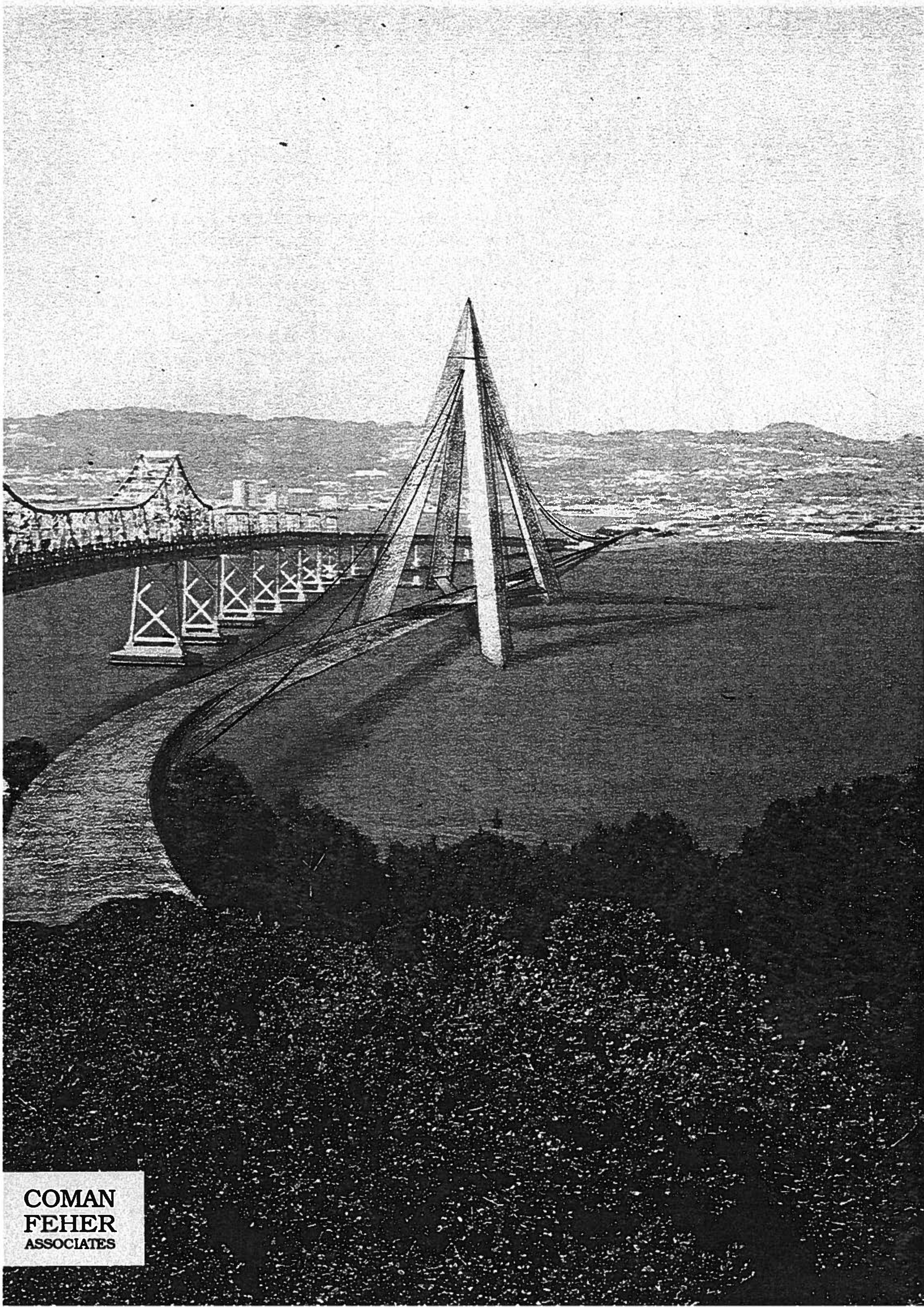
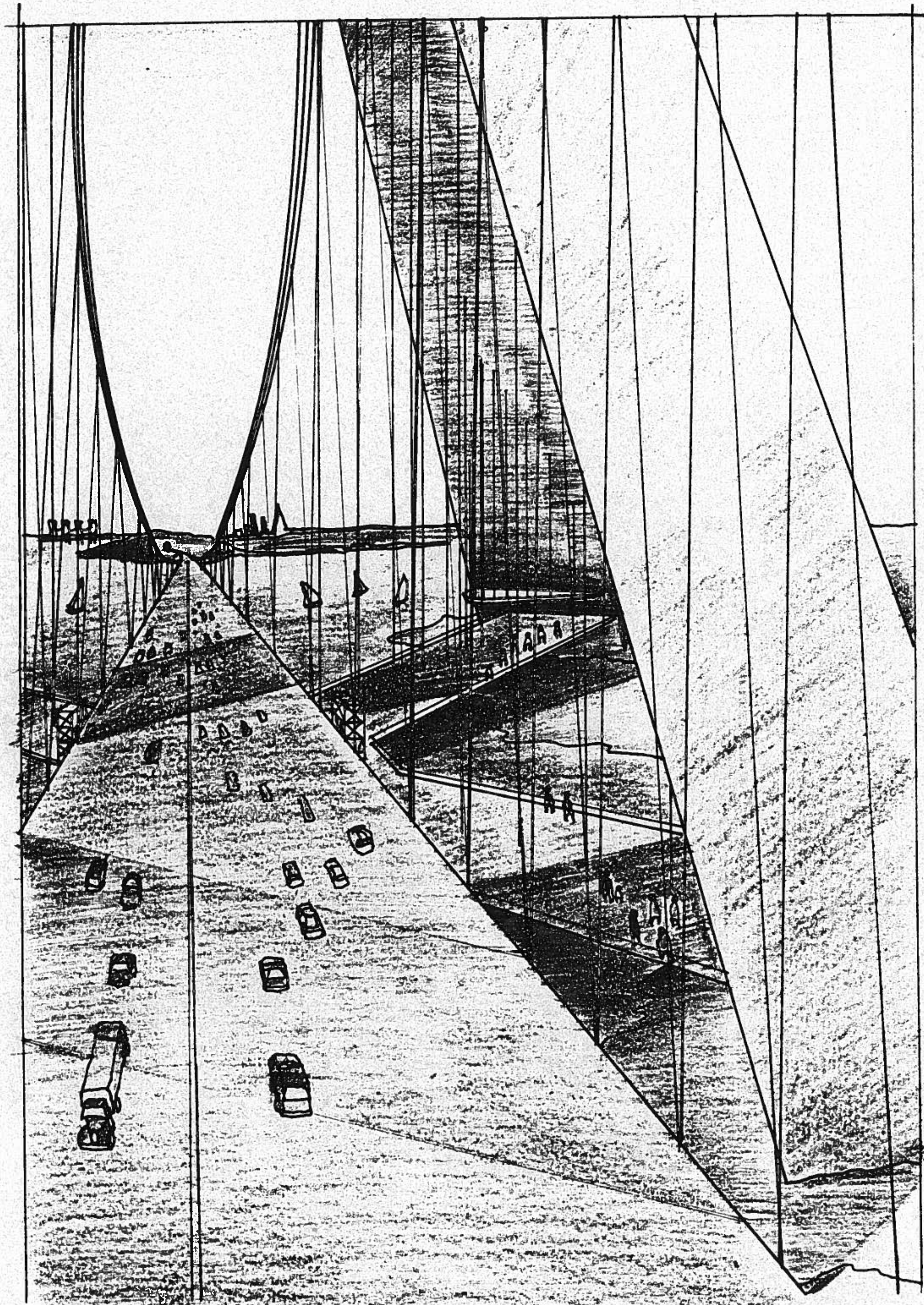
EAST SPAN REPLACEMENT OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE



COMAN
FEHER
ASSOCIATES



A Bridge and More

BY RICK FEHER AND DANIEL COMAN

The decision to replace the eastern span of the San Francisco-Oakland Bay Bridge created an opportunity to assess experience acquired in this century and apply it to a bridge which will span the millenium. Future generations will learn either that we lacked vision and confidence toward the end of this century, or else they will be inspired by the way we gracefully combined our growing awareness of nature's limits with our own limitless imaginations.

We believe there is a common-sense process which can be used to evaluate *any* proposal for a new San Francisco-Oakland Bay Bridge.

Let us start with some assumptions.

DESIGN ASSUMPTIONS

1. Seismic safety will be a primary consideration, maximal for all probable quake scenarios.

2. For public safety, the bridge will be completed in the shortest possible time, to minimize the risk that a large earthquake would destroy the existing Bay Bridge before the new bridge is complete.

3. Quality will be maximized at the same time that costs are kept down. This implies a maximum of prefabricated elements, clever logistics, simplicity.

4. The new bridge will minimally impact the bay, conserving *as much as possible* natural relationships between land and water.

5. The new bridge will do more for the communities it serves than merely convey traffic, and will reflect the aspirations and possibilities of our time just as the time-honored works of our forefathers did in their time.

If we consider that tourism in the Bay Area was reported in the San Francisco Chronicle to be at 3.5 million tourists per year with 2.5 billion dollars in tourism revenue, we can assume too that tourism ought to be remembered when building a large functional monument which most of those tourists will use.

If we consider the growing number of alternatives to the automobile and the growth in alternative-transportation advocacy, it is clear that *integral to the design* should be pedestrian, wheelchair, bicycle, etc., access for trans-bay commuting and touring, and that such provision should in no way be considered an afterthought.

If we consider that the open-truss railroad bridge evokes the industrial character of West Oakland and that Oakland is now in transition, then the bridge on the Oakland side ought to reflect the visions and aspirations of Oakland's inhabitants.

DESIGN OPTIONS EXAMINED

With the above assumptions clearly in mind, the various designs may be examined to find whether or not they meet basic criteria.

Design solutions to be avoided:

Rigid bridges which need the addition of special means to mitigate their inherently inelastic nature.

Structures which principally rely for their stability upon piles driven into geological formations prone to fluidization which will induce hydrodynamic forces upon the piles during a seismic event.

Non-unitary (anisotropic) structures that arbitrarily and unnecessarily combine two or more unlike structural systems, such as cable-stayed bridges attached to viaducts.

Bridges with numerous in-bay supports that create an artificial barrier across the natural expanse of the bay.

Structures that impinge unduly, visually and physically, upon the geographical features of the bay, particularly Yerba Buena Island, which is small in relation to the massive structures which bear upon it.

Trendy, ephemeral aesthetic statements (neo-classical, post-modern, neo-gothic, neo-art-deco, neo-victorian), or pallid imitations of past achievements such as a copy of an existing bridge in the bay which would inevitably diminish both.

The Loma Prieta, Northridge and Kobe quakes demonstrated that cable-stayed or suspension bridges are safer than reinforced-concrete, post-and-beam constructions. Notable was the tremendous, swift upthrust of the Northridge quake which forced columns upward and through the massively inertial roadbeds. It is in vain that one attempts to dampen such immense forces with seismic isolators added to rigid connections.

The proposed skyway also contradicts the design assumptions in other ways. There are to be 19 sets of three columns, poured in place, with each set anchored in a unitary foundation with driven-pile footings. Neither time (inverse to public safety) nor cost can be minimized for these operations. Nineteen intrusions into the bay present no improvement over the existing bridge, which also has 19 pylons in the water. And there is a greater risk in the skyway that a quake would induce destructive resonant oscillations.

Each option to the skyway consitsts of a cable-stayed bridge which leaves Yerba Buane Island, follows a straight course out of the tunnel for a couple of thousand feet and abruptly ends. There is a splice, and the skyway takes over, changes direction in the middle of the bay and heads back toward Oakland. This longer-than-necessary trick cannot be justified by supposing a need for a shipping lane under the 2,000-foot span between the towers of the cable-stayed part of the bridge, since the shallow waters at that location already prevent the passage of any sizeable vessels. Nor is any dredging option envisioned due to known problems with dredging and disposal of contaminated bay mud.

The Kobe earthquake demonstrated that cable-stayed bridges are safer than concrete elevated freeways. Both types of roadway were engineered to tolerate huge seismic forces but one of them was *conceptually and empirically* superior. Engineers who are aware of the dangerous proposition of connecting two bridges which oppose each other dynamically (during an earthquake, or in high winds) ought to know that such options can only be justified on *aesthetic* grounds—strange aesthetics which include the ugly prospect of a bridge breaking in two. Why should the new bridge be in two parts? Why should part of the bridge be safer than the rest? And why should the safer part be the *smaller* part?

Oaklanders have asked why the inferior part, and the part not "aesthetically tweaked" is still on the San Francisco end.

At present, we have a Bay Bridge in two parts, and we are committed to replacing the inferior part. It was considered inferior from 1937 till 1989, and unsafe since then. We have an opportunity to make a world-class bridge in a place where the world will look to see what standard has been set.

COMAN FEHER PROPOSAL

In view of the above discussion, and after studying contemporary bridge projects worldwide, we propose the following design for the replacement of the eastern span of the San Francisco-Oakland Bay Bridge:

A two-span suspension bridge situated along a straight alignment south of the existing SFOBB, with a central, mid-bay cable tower and anchorages at Oakland and Yerba Buena Island, respectively. (Figure 1.)

SPECIFIC CHARACTERISTICS, FUNCTIONS AND COMPONENTS

The central tower, which supports the main suspension cables, is the sole in-bay element.

The bridge deck consists of prefabricated box-beam segments.

The tower is a tetrapod with reinforced concrete legs founded in bedrock, which straddle the bridge deck and converge above it.

The apex of the tower above the main cables comprises an interior observation deck and several inhabitable floors accessible by elevators installed in the tubular legs of the tower.

A cable-stayed lower deck under the tower provides for bike, gondola, pedestrian and boat access to the tower elevators.

A bicycle path and cable gondola are suspended under the deck. The design of both bike path and gondola is suitable and intended for attachment under the existing western span of the SFOBB.

Wildlife refuge island around base of tower serves as bumper against marine collision.

STRUCTURAL CONSIDERATIONS

A central-tower suspension design was adopted in large part for seismic considerations. The anchoring of the tower and its geometry and mass below the waterline are considered to have a high tolerance to hydrodynamic forces such as observed in the fluidization of silt and clay at Bootlegger Cove, Alaska in 1964. Deflection characteristics as the legs ascend and the dynamic relationships of tower, cable, deck and anchorages are to work synergetically to achieve a high degree of damping and cancellation of resonance during seismic events.

The main structural elements of the central tower are four reinforced-concrete, slip-formed, tubular legs with equilateral-triangular cross sections. (Figure 2.) The legs form a square which is 172 meters on a side at sea level. At an elevation of 35 meters the deck passes between the legs, which rise to an elevation of 336 meters. (Figure 3.) From sea level the legs descend through water and silt, reaching bedrock, where each is anchored and founded.

Deck in cross-section is an inverted airfoil affording superior aerodynamic stability. (Figure 3.) Each deck module is fabricated of extruded aluminum profiles as a honeycomb-core torsion box. Segments are joined one to the next by a system of welds, mechanical joinery and adhesives. Joinery employs thermoplastic carbon fiber composites. (Figure 4.)

Basic geometrics and engineering assumptions are based upon proven suspension designs, notably the Humber Bridge over the Humber River estuary in northeastern England. (Figure 5.)

Twin suspension cables, each composed of three distinct cables (figure 6) are of sheathed liquid crystal polymer fibers. These are light-weight (specific gravity 1.4), with ultra-high tensile strength, close to zero thermal expansion, zero creep and are highly resistant to corrosive agents. Cable house in tower comprises a pulley system where the continuous shore-to-shore cables converge and bear upon the unified structure of the tetrapod. Main cables diverge toward shore to improve damping characteristics.

Alternatively, steel may substitute for aluminum and polymer fibers with minimal load adjustments and no change in design assumptions.

UNIQUE AND SUPERIOR FEATURES

Seismically proven isotropic structure; seismic considerations guide the design throughout.

Prefabrication of major elements, slip-form tower, fewer in-bay sites and lightweight cables and deck facilitate rapid erection, reduce labor costs and reduce overall costs.

Observation deck and visitor attractions provide substantial revenue for payback of bridge.

Bike path is absolutely separated from automobile traffic and is free from exhaust and flying matter from automobiles, and the noise of traffic. A unique, safe, serene ride is possible between Oakland and San Francisco with spectacular views.

Cable gondolas provide revenue and clean public transportation.

Gondolas and bike path have routing to San Francisco and Oakland as well as to Yerba Buena and Treasure islands and to the tower. This enhances development plans for Treasure Island.

Fewer intrusions into the bay; bridge does not have multiple pylons and therefore does not appear, fencelike, to cut the bay in half. Single, central excavation causes less disruption to sensitive fish, pinnipeds and waterfowl.

Excavation into contaminated silt is reduced by having only four central excavations instead of nineteen. This in itself reduces the disposal problem to only one-eighth of other proposals. Additionally, since restored shore-line habitat (island) will surround the tower, the topmost silt (the most contaminated) can be disposed of by leaving it at the site, six meters below the new island.

Gondolas, bike path and tower will enhance tourism on both sides of the bay, and will re-orient development, particularly on the Oakland side.

ERECTION SEQUENCE

At the exact center of the tetrapod site, a circular array of tubular steel piles is driven to bedrock. A pyramid-shaped superstructure of reinforced concrete is erected above water level. (Figure 7.)

At the locations of the four legs of the tetrapod, caissons are lowered to bedrock (figure 7), material is excavated, tie-downs and anchorages are drilled into the Franciscan complex and foundations are poured. Legs are slip-form erected to a pre-determined height. At that height, crane segments are attached to embedded plates in the previously erected portions of the legs and connected to the pyramid structure at the exact center of the tetrapod for diagonal bracing. (Figure 8.) Following a similar process, the legs are slip-formed continuously upward with alternately placed crane segments to achieve suitable rigidity and seismic worthiness during the entire process of erection. (Suitable terminations for the crane segments will be fabricated, while the crane segments themselves may be leased.) Terminations at opposite ends of each crane-segment brace will be joined by tensioned cables.

Anchorages. Yerba Buana Island anchorages will be tunnel-bore-type, or the most economically suitable for the geologic structure at the anchorage site. On the Oakland side, a gravity anchorage will be installed, supported against slippage due to possible liquefaction of soils by suitable steel piles driven into the upper (or, if necessary, the lower) Alameda formation. Piles will form a linear array at every Oakland-site anchorage of suitable length to elminate displacements.

Main suspension cables. Each suspension cable is composed of three distinct cables (figure 6), increasing redundancy and minimizing the lifting power required to elevate cables to the tower. The cables are arrayed horizontally parallel to each other, reducing windage and minimizing the visual profile for less intrusive presence into the bay skyline. Cables will be continuous the length of the bridge, strung out across the bay and anchored at each end. They will be lifted on the sloping legs of the tower by hydraulic means on embedded track at the edges of the tower. At the top of the tower, all of the cables will rest on specially designed pulleys which will minimize or eliminate changes in the cables' geometry in the event of a seismically induced precession of the tower's apex.

Although steel cables are suitable for this design, we have researched and selected cables made of Vectran (™), a liquid-crystal polymer melt-spun fiber manufacturered by Hoechst-Celanese.) Each individual cable—of a total of six—is composed of linear parallel fibers of Vectran sheathed with braided Kevlar, manufactured as a 13mm rope by a manufacturer of climbing rope. These ropes are then formed into 160mm cables surrounded by suitable barriers against moisture, UV, heat, etc. (We have designed those details as well.)

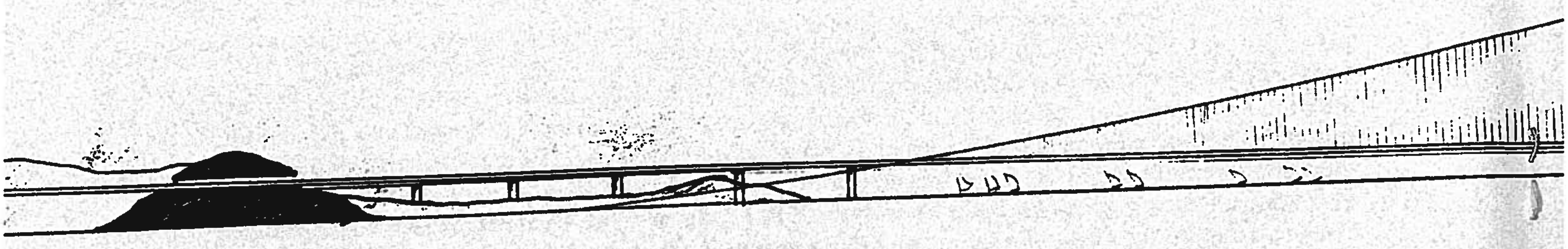
Deck. The deck is an assemblage of approximately 6,000 modules (figure 4), put in place with the aid of rolling cranes travelling on pulleys along the main cables. Each module is a section of a honeycomb-core torsion box manufactured entirely by fully automated existing processes out of extruded aluminum profiles, the surfaces of which, where exposed to the elements, are treated by a process of plasma sputtering with an alloy film which is impervious to corrosion. When fully assembled, each module is pressure-tested, its interior is dehydrated and the air is flushed with nitrogen at slightly higher than atmospheric pressure. Each deck module will be equipped at one end with a valve and a pressure sensor so that, in the event of a failure of welds between the deck modules, pressure in a built-in channel above the main welds at top and bottom of deck will experience a sudden drop, which will be noted by the bridge's computerized monitoring system. Strain gauges will be installed in the legs of the tower, at the anchorages and throughout all structural elements which are expected to experience deflection during an earthquake.

Bicycle deck. After the main deck final assembly, a similarly extruded bicycle deck is hung below it at a distance of 3 meters by means of diagonally joined semicircular extruded aluminum pipes. Five-millimeter steel cables with 10cm spacing will be tensioned between the pipes as an unobtrusive barrier. At the location where the pipes join the bicycle deck, specially designed brackets support pulleys for the gondola cable transportation system, identical to ski-resort systems such as one at Squaw Valley.

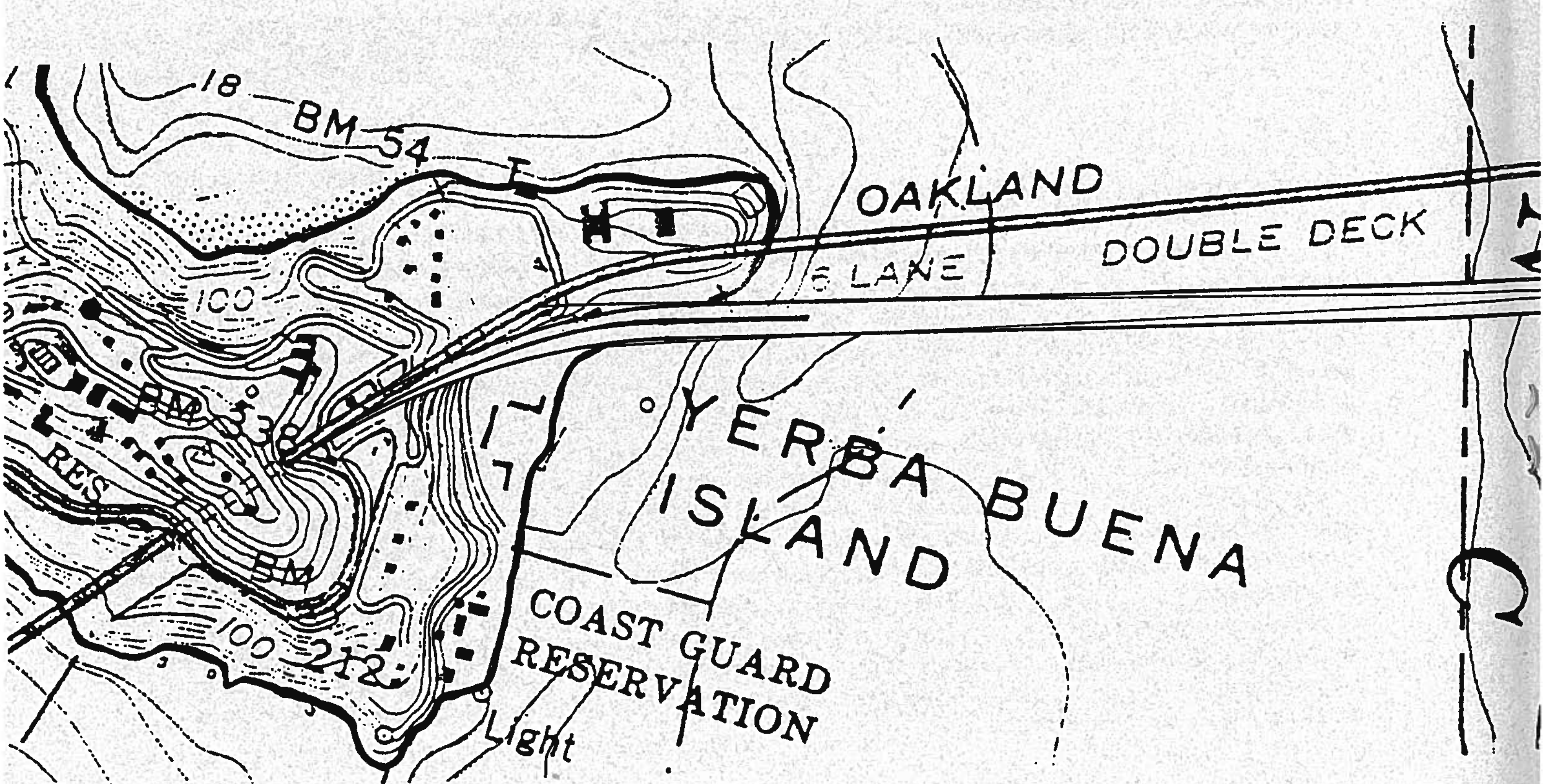
TOWER VISITOR FACILITIES

At the tower location and below both the auto and bicycle decks, a cruciform pedestrian deck is suspended by cable stays between the legs of the tower, its center being supported by diagonal steel pipes on the central, reinforced-concrete pyramid. Stairways and elevators for both the east- and west-bound lanes connect all the bridge decks with the main deck below. Additionally, from this main pedestrian deck, access to boat ramps is provided for the tourists and passengers arriving from San Francisco and Oakland and all other waterfront locations. The boat dock is entirely surrounded by restored shoreline constructed out of the excavated material which provides habitat for wildlife such as cormorants displaced by demolition of the existing bridge. From the main pedestrian deck, elevators ascend inside the tubular legs to the observation deck which is 280 meters above water level. The observation deck covers an area of approximately 900 square meters and a height of six meters. All four walls are double-pane glass panels connected to the tubular space-frame structure of the tower's apex. It will accommodate promotional stations for public agencies such as California State Park Service, the Golden Gate Recreational Area, etc. A second set of elevators conveys visitors to six or seven additional floors above. There you will find a restaurant, cafés, an astronomical observatory, a live internet conference center with huge screens, etc. Moreover, the very apex of the tower with its 60-mile horizon will have line-of-sight to all Bay Area locations and will therefore serve as the nexus for a laser-based data network.

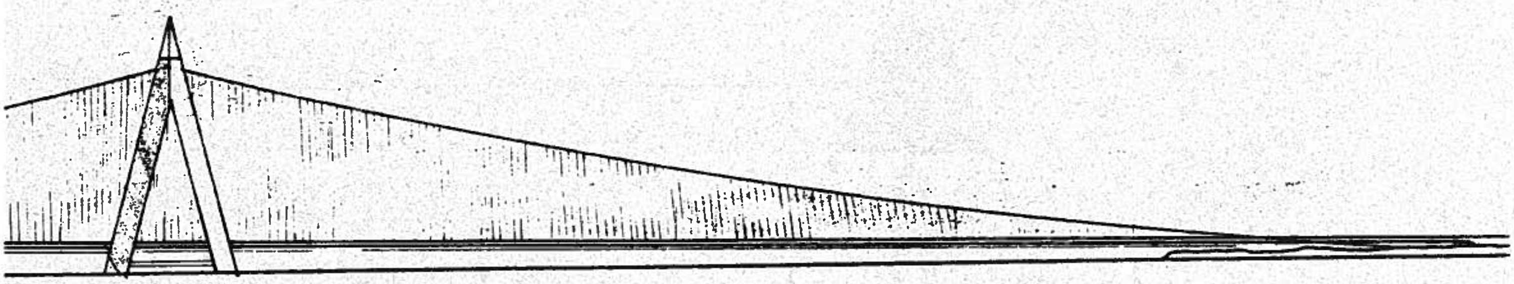
FIGURE



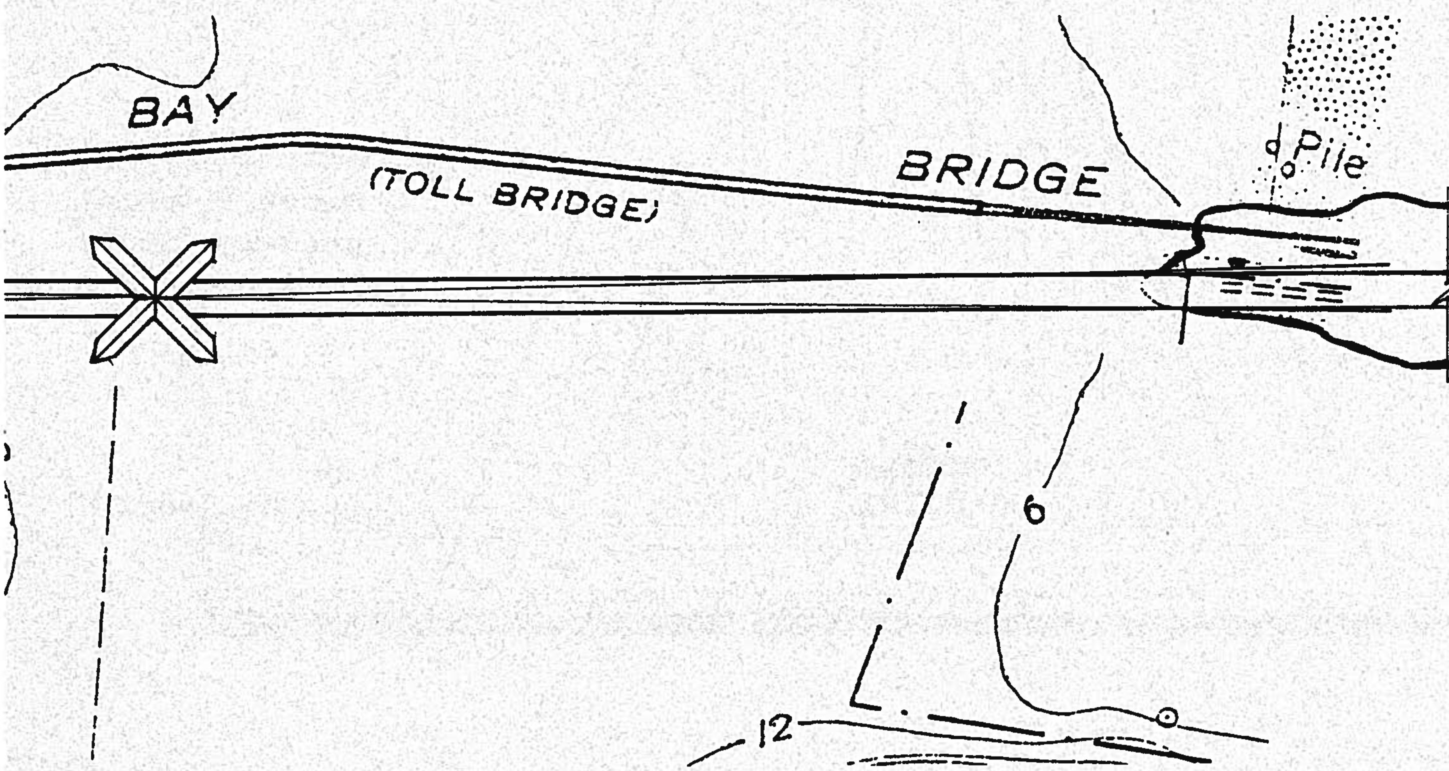
SOUTH ELEVAT



SITE PLAN-



ON—1:10,000



10,000

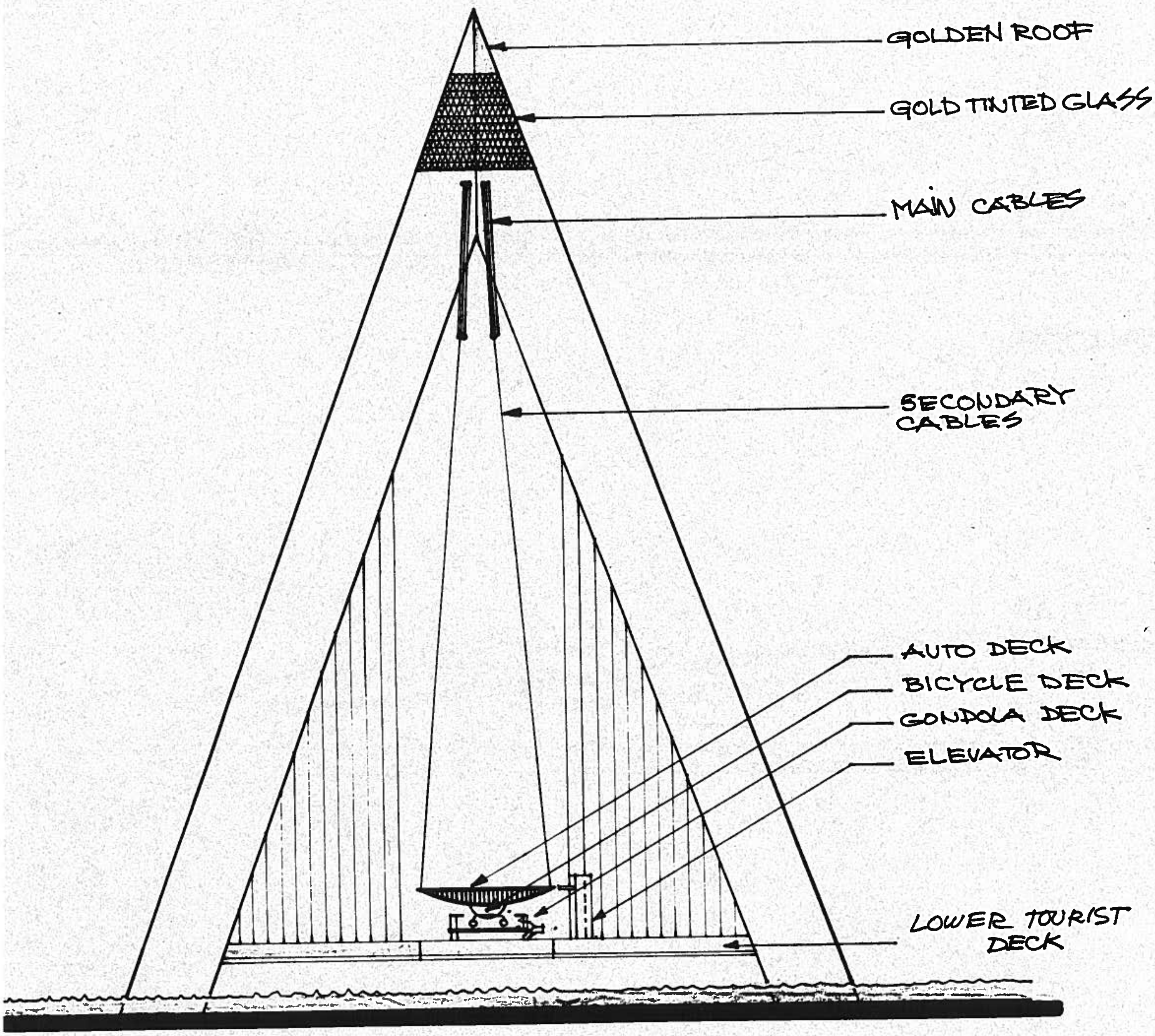

GOLDEN ROOF
GOLD TINTED GLASS
MAIN CABLES
SECONDARY CABLES
AUTO DECK
BICYCLE DECK
GONDOLA DECK
ELEVATOR
LOWER TOURIST DECK

FIGURE 3

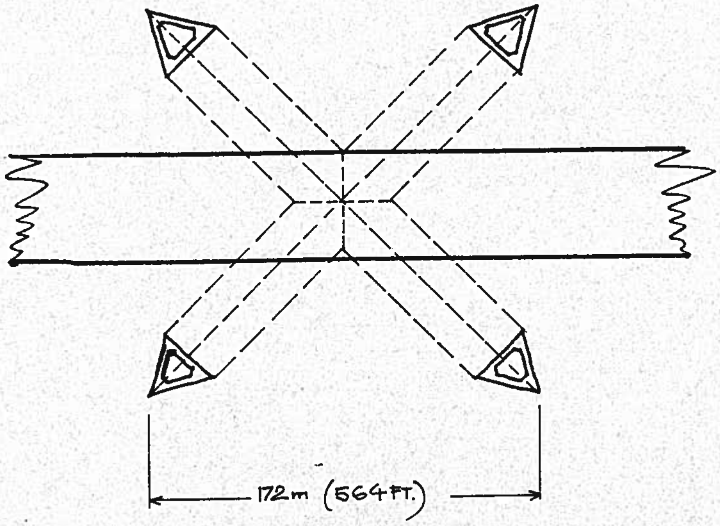


FIGURE 2

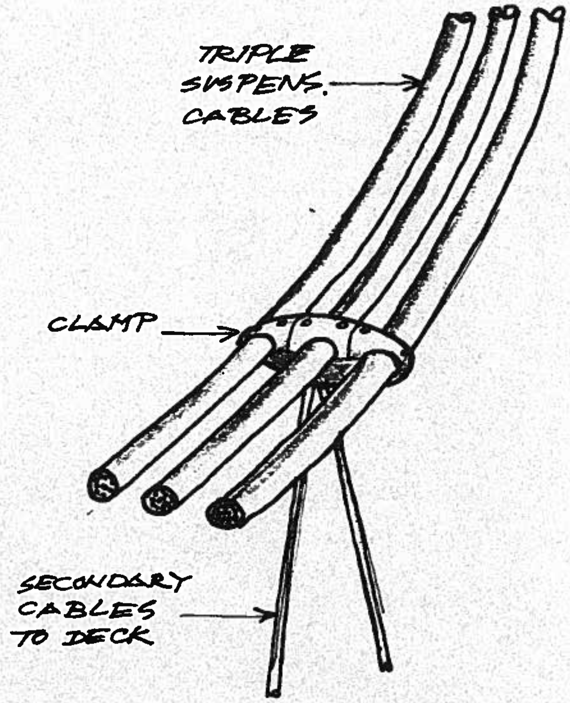


FIGURE 6

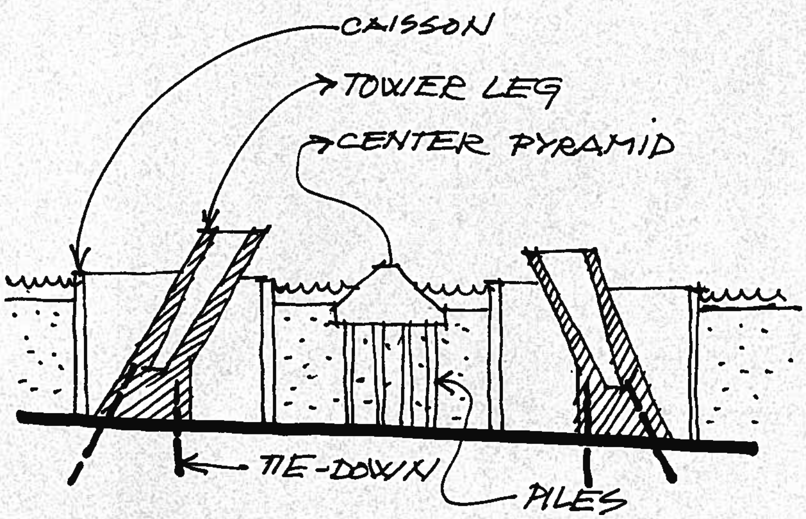


FIGURE 7

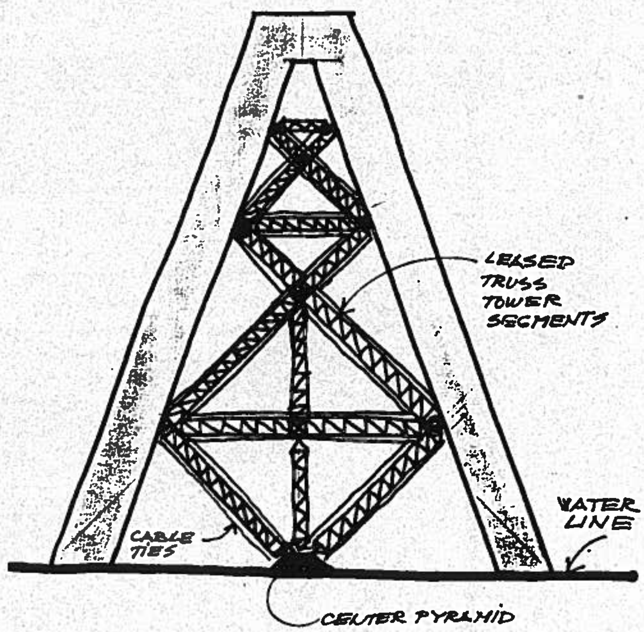
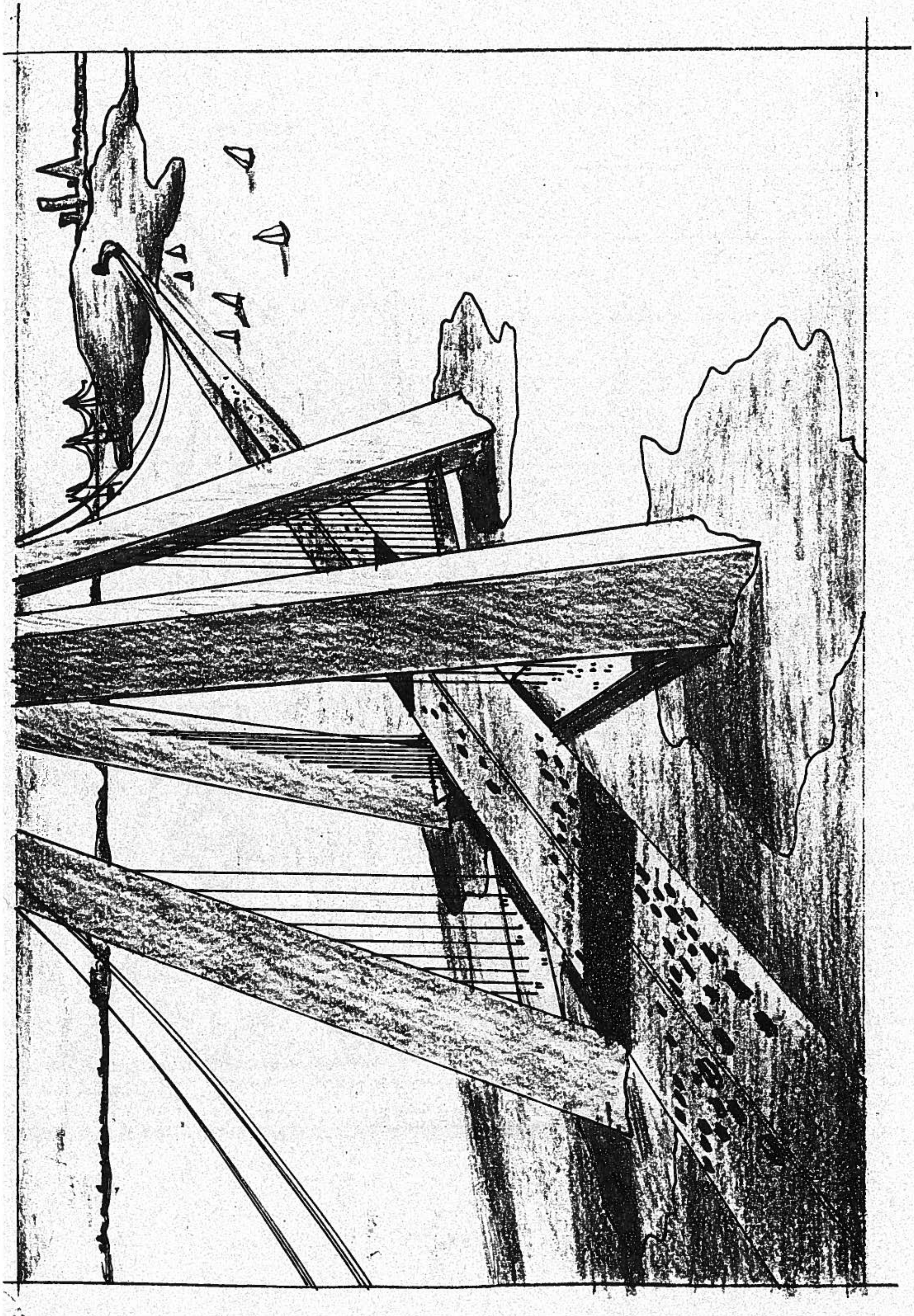
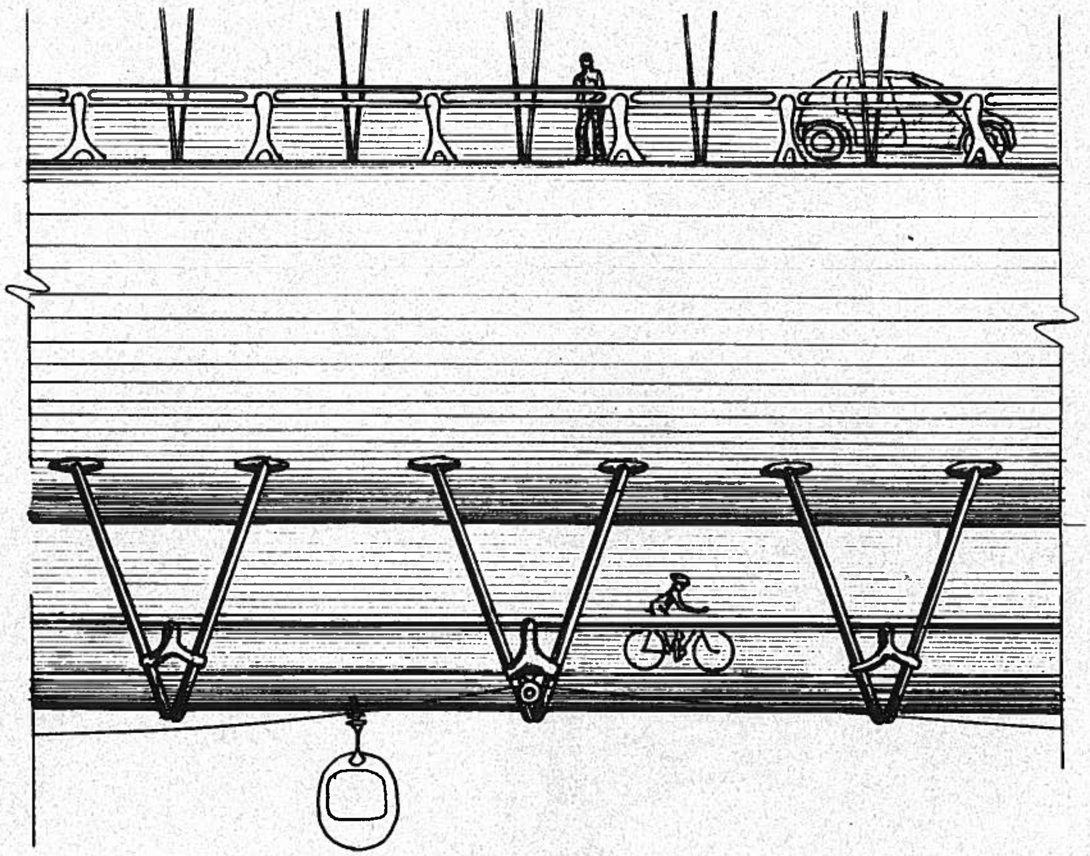
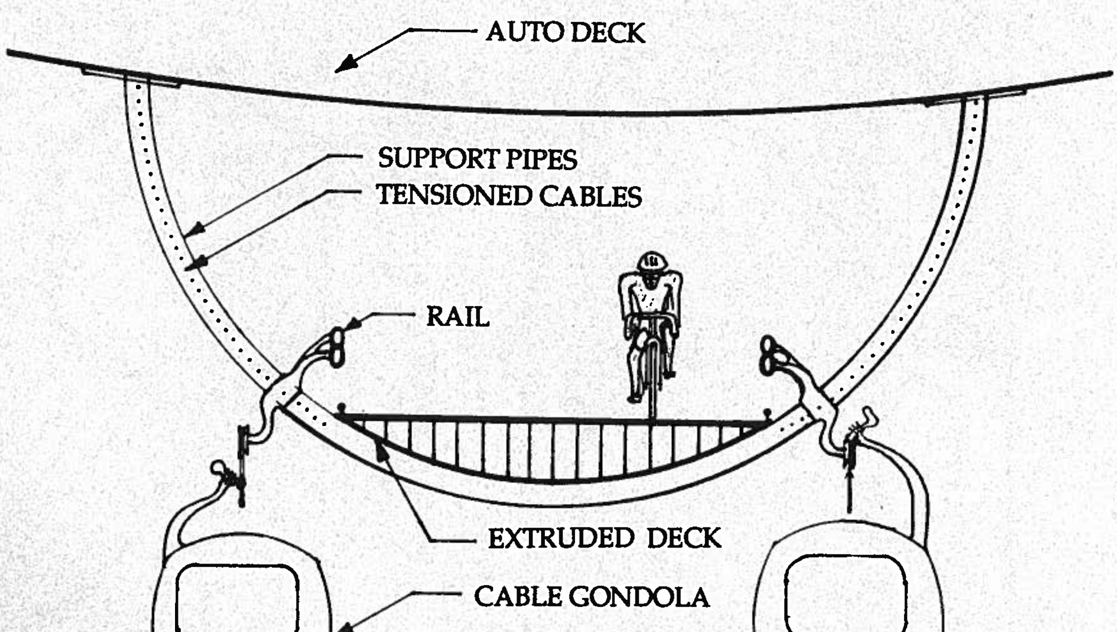


FIGURE 8





BRIDGE DECK PARTIAL ELEVATION



BICYCLE PATH CROSS SECTION

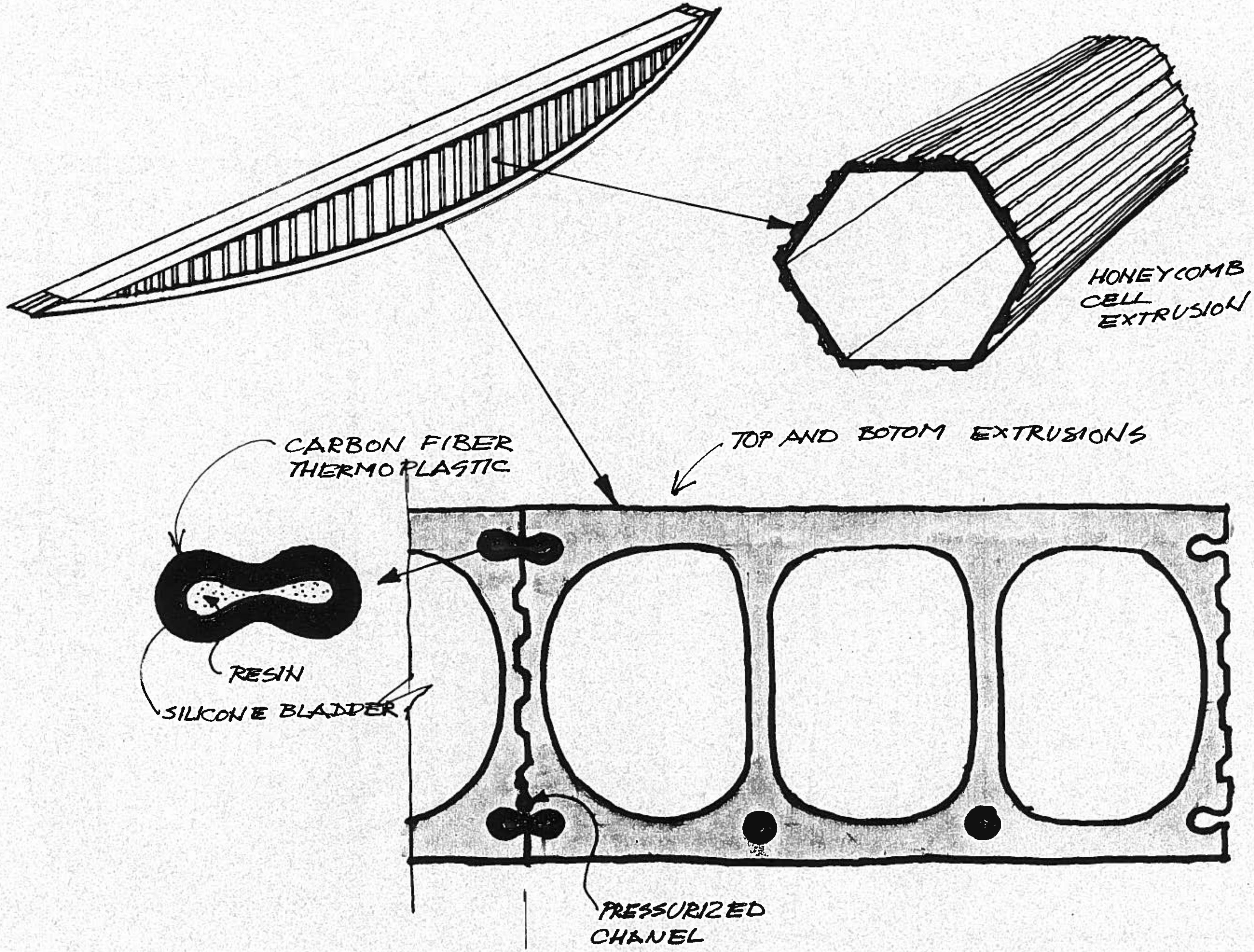

HONEYCOMB CELL EXTRUSION
CARBON FIBER THERMOPLASTIC
TOP AND BOTOM EXTRUSIONS
RESIN
SILICONE BLADDER
PRESSURIZED CHANEL

FIGURE 4

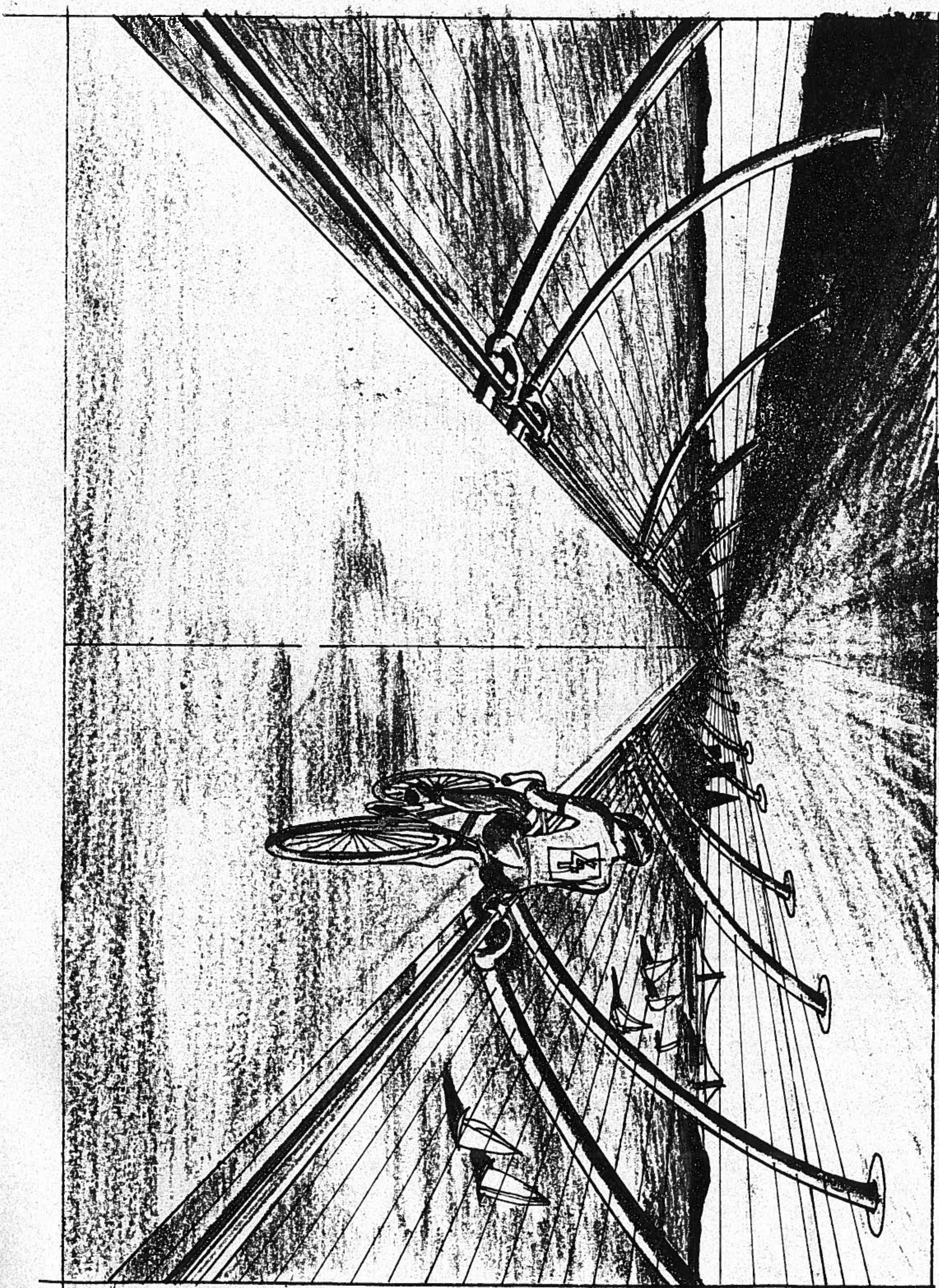
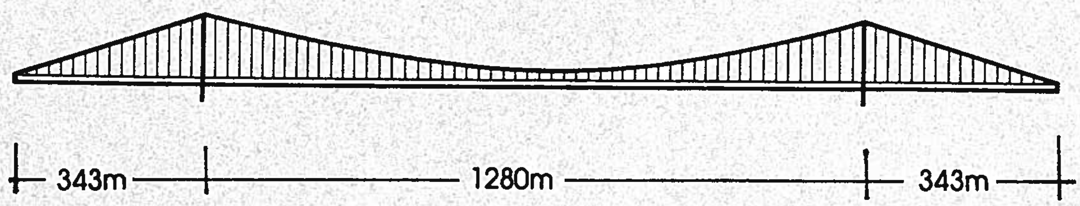
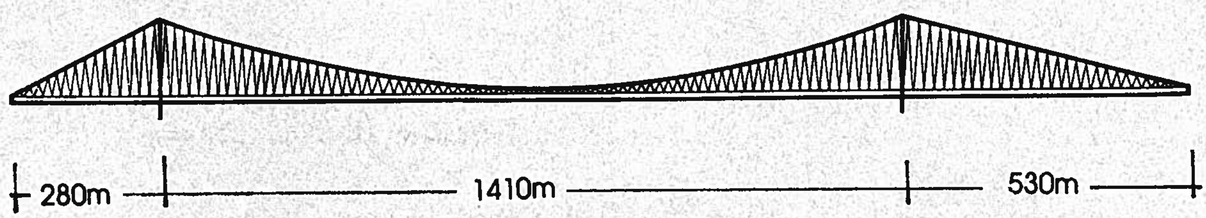


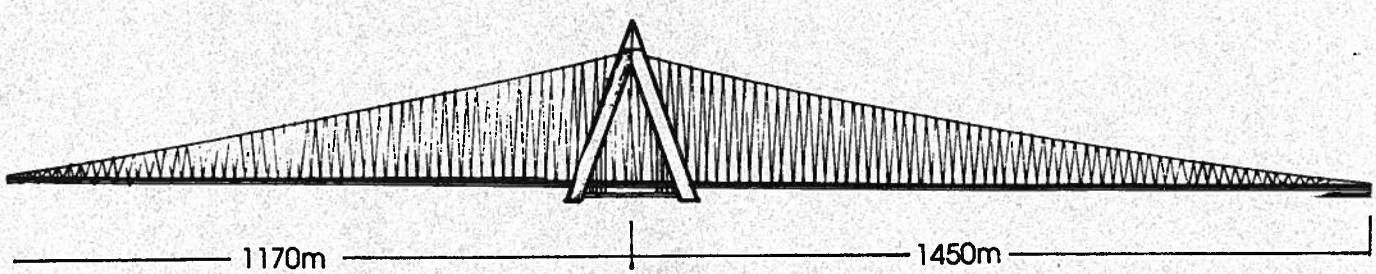
FIGURE 5



GOLDEN GATE BRIDGE



HUMBER BRIDGE



SAN FRANCISCO-OAKLAND BAY BRIDGE

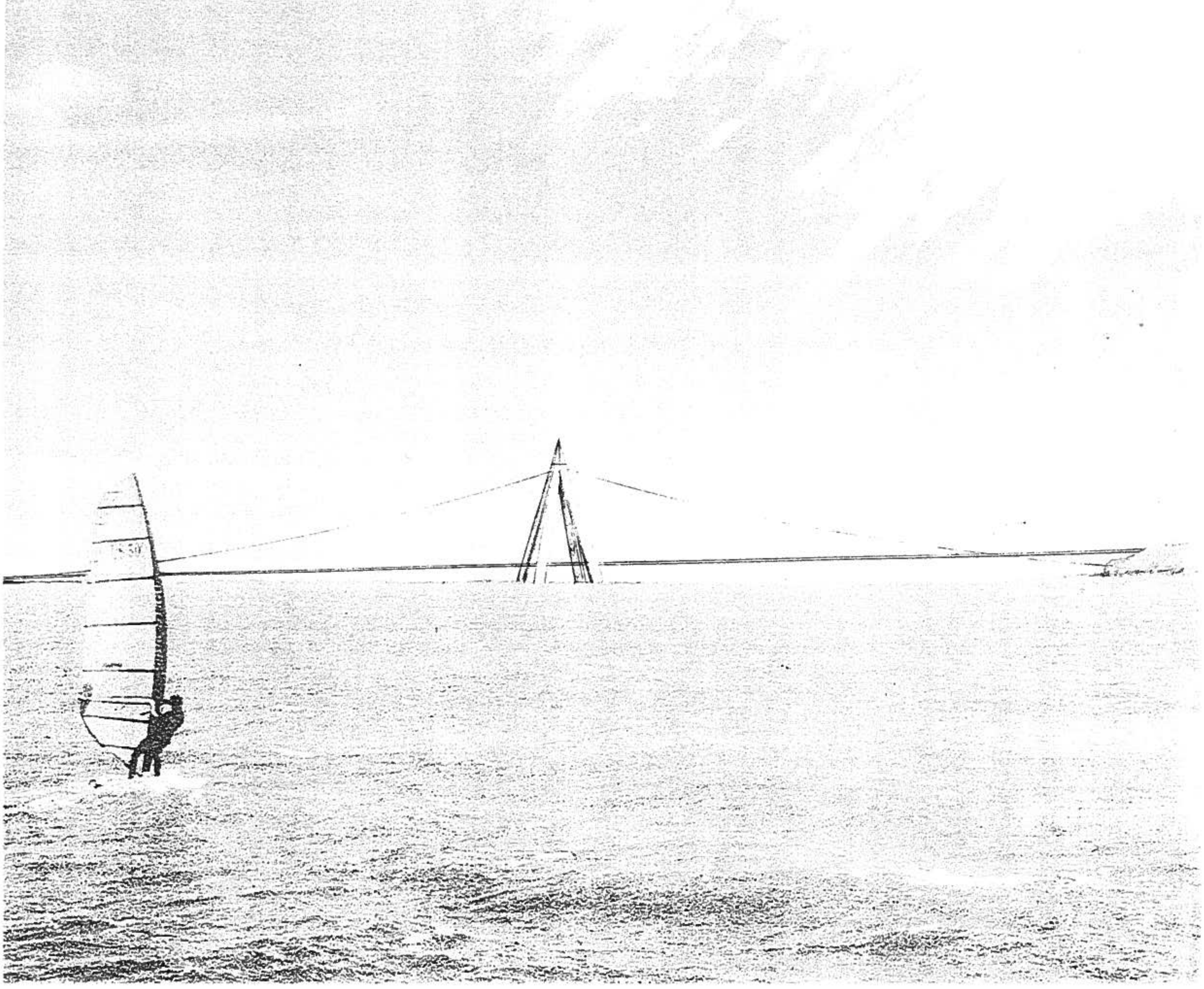
COMAN
FEHER
ASSOCIATES

401 39th Street Sacramento, CA 95816 (916) 731-8880 fax: (916) 739-6951

EAST SPAN REPLACEMENT OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE

Initial Submittal
Metropolitan Transportation Commission's
Bay Bridge Design Task Force
Engineering and Design Advisory Panel
May 6, 1997

COMAN
FEHER
ASSOCIATES



COMAN
FEHER
ASSOCIATES

Initial submittal
Metropolitan
Transportation Commission's
Bay Bridge Design Task Force
Engineering and Design Advisory Panel
May 6, 1997

EAST SPAN REPLACEMENT
OF THE
SAN FRANCISCO-
OAKLAND BAY BRIDGE

GENERAL DESCRIPTION

This proposal describes a two-span suspension bridge situated along a straight alignment south of the existing SFOBB, with a central, mid-bay cable tower and anchorages at Oakland and Yerba Buena Island, respectively.

SPECIFIC CHARACTERISTICS, FUNCTIONS AND COMPONENTS

The central tower, which supports the main suspension cables, is the sole in-bay element.

The bridge deck consists of prefabricated box-beam segments.

The tower is a tetrapod with reinforced concrete legs founded in bedrock, which straddle the bridge deck and converge above it.

The apex of the tower above the main cables comprises an interior observation deck and several inhabitable floors accessible by elevators installed in the tubular legs of the tower.

A cable-stayed lower deck under the tower provides for bike, gondola, pedestrian and boat access to the tower elevators.

A bicycle path and cable gondola are suspended under the deck. The design of both bike path and gondola is suitable and intended for attachment under the existing western span of the SFOBB.

Wildlife refuge island around base of tower serves as bumper against marine collision.

STRUCTURAL CONSIDERATIONS

A central-tower suspension design was adopted in large part for seismic considerations. The anchoring of the tower and its geometry and mass below the waterline are considered to have a high tolerance to hydrodynamic forces such as observed in the fluidization of silt and clay at Bootlegger Cove, Alaska in 1964. Deflection characteristics as the legs ascend and the dynamic relationships of tower, cable, deck and anchorages are to work synergetically to achieve a high degree of damping and cancellation of resonance during seismic events.

The main structural elements of the central tower are four reinforced-concrete, slip-formed, tubular legs with equilateral-triangular cross sections. The legs form a square which is 172 meters on a side at sea level. At an elevation of 35 meters the deck passes between the legs, which rise to an elevation of 336 meters. From sea level the legs descend through water and silt, reaching bedrock, where each is anchored and founded. Injected-concrete piles descend from the legs near the base toward the interior of the tetrapod, widening each leg's effective bearing and providing support during construction.

STRUCTURAL CONSIDERATIONS (continued)

Deck in cross-section is an inverted airfoil affording superior aerodynamic stability. Each deck module is fabricated of extruded aluminum profiles as a honeycomb-core torsion box. Segments are joined one to the next by a system of welds, mechanical joinery and adhesives. Joinery employs thermoplastic carbon fiber composites.

Basic geometrics and engineering assumptions are based upon proven suspension designs, notably the Humber Bridge over the Humber River estuary in northeastern England.

Suspension cables are of sheathed liquid crystal polymer fibers. These are light-weight (specific gravity 1.4), with ultra-high tensile strength, close to zero thermal expansion, zero creep and are highly resistant to corrosive agents. Cable house in tower comprises a pulley system where the continuous shore-to-shore cables converge and bear upon the unified structure of the tetrapod. Main cables diverge toward shore to improve damping characteristics.

Alternatively, steel may substitute for aluminum and polymer fibers with minimal load adjustments and no change in design assumptions.

UNIQUE AND SUPERIOR FEATURES

Seismically proven isomorphic structure; seismic considerations guide the design throughout.

Prefabrication of major elements, slip-form tower, fewer in-bay sites and lightweight cables and deck facilitate rapid erection, reduce labor costs and reduce overall costs.

Observation deck and visitor attractions provide substantial revenue for payback of bridge.

Bike path is absolutely separated from automobile traffic and is free from exhaust and flying matter from automobiles, and the noise of traffic. A unique, safe, serene ride is possible between Oakland and San Francisco with spectacular views.

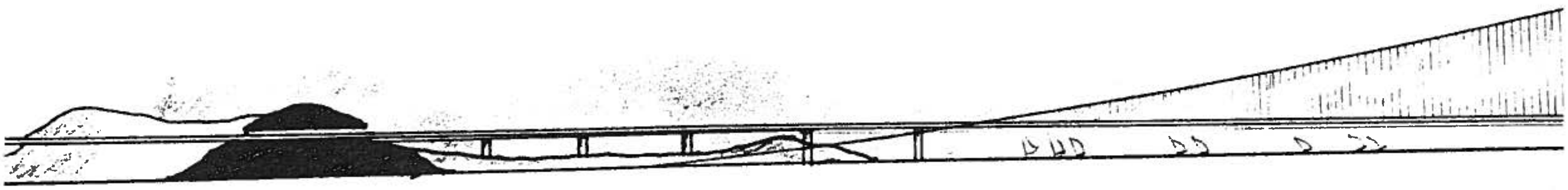
Cable gondolas provide revenue and clean public transportation.

Gondolas and bike path have routing to San Francisco and Oakland as well as to Yerba Buena and Treasure islands and to the tower. This enhances development plans for Treasure Island.

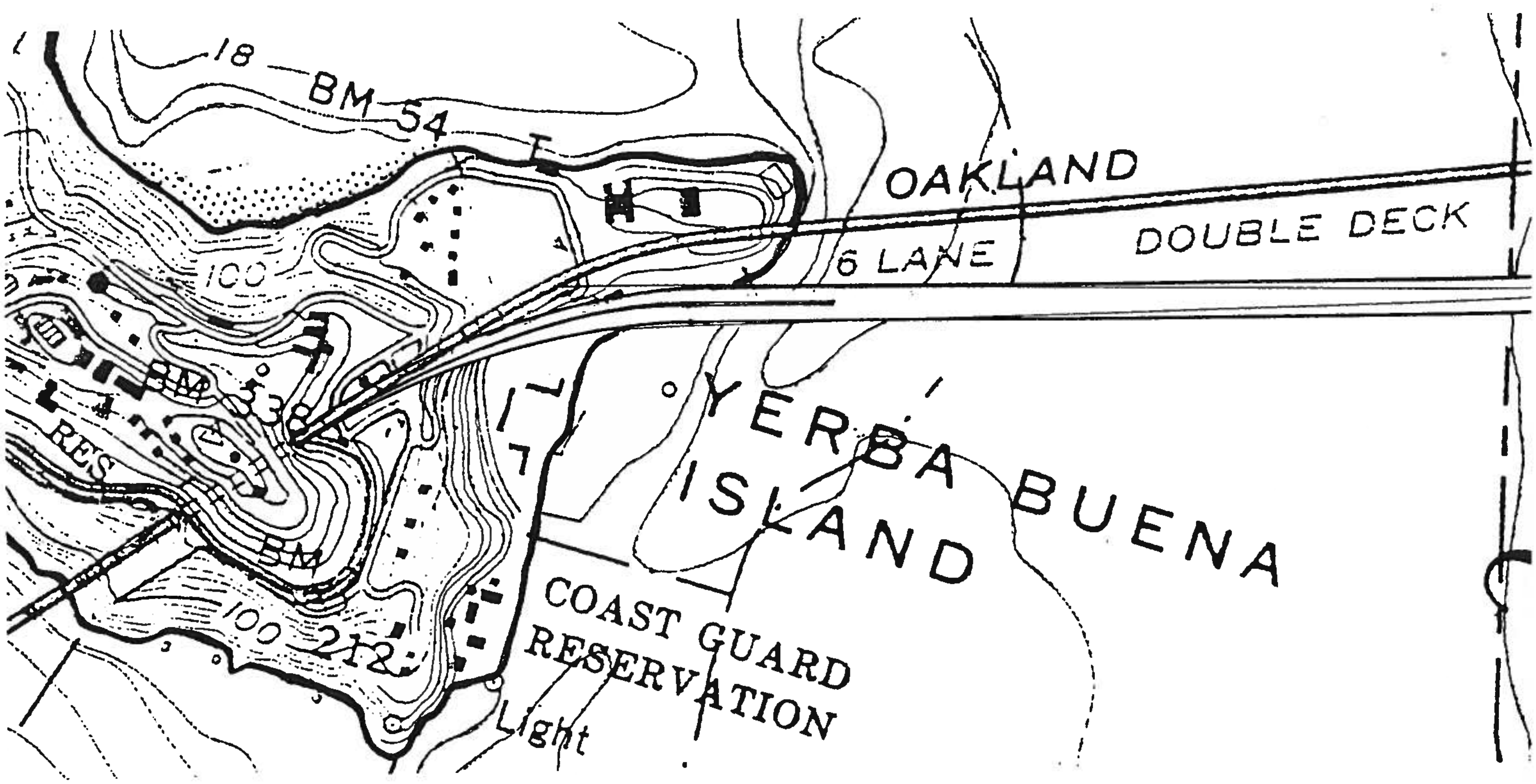
Fewer intrusions into the bay; bridge does not have multiple pylons and therefore does not appear, fencelike, to cut the bay in half. Single, central excavation causes less disruption to sensitive fish, pinnipeds and waterfowl.

Excavation into contaminated silt is reduced by having only four central excavations instead of nineteen. This in itself reduces the disposal problem to only one-eighth of other proposals. Additionally, since restored shore-line habitat (island) will surround the tower, the topmost silt (the most contaminated) can be disposed of by leaving it at the site, six meters below the new island.

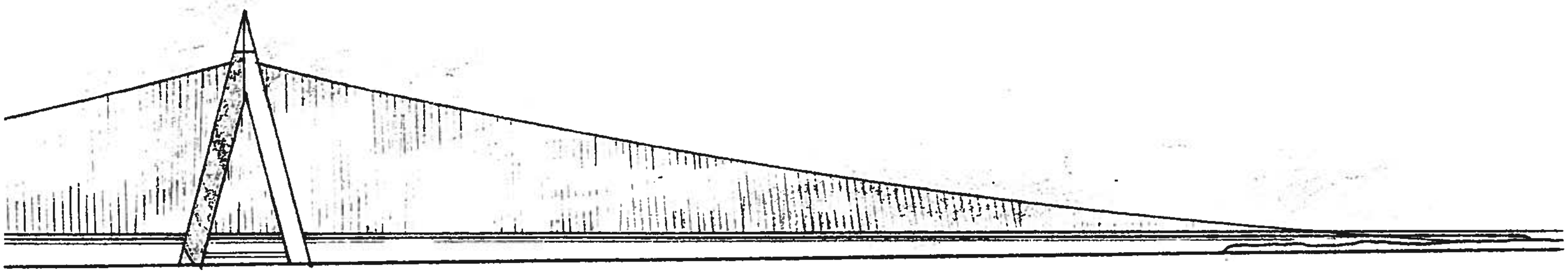
Gondolas, bike path and tower will enhance tourism on both sides of the bay, and will re-orient development, particularly on the Oakland side.



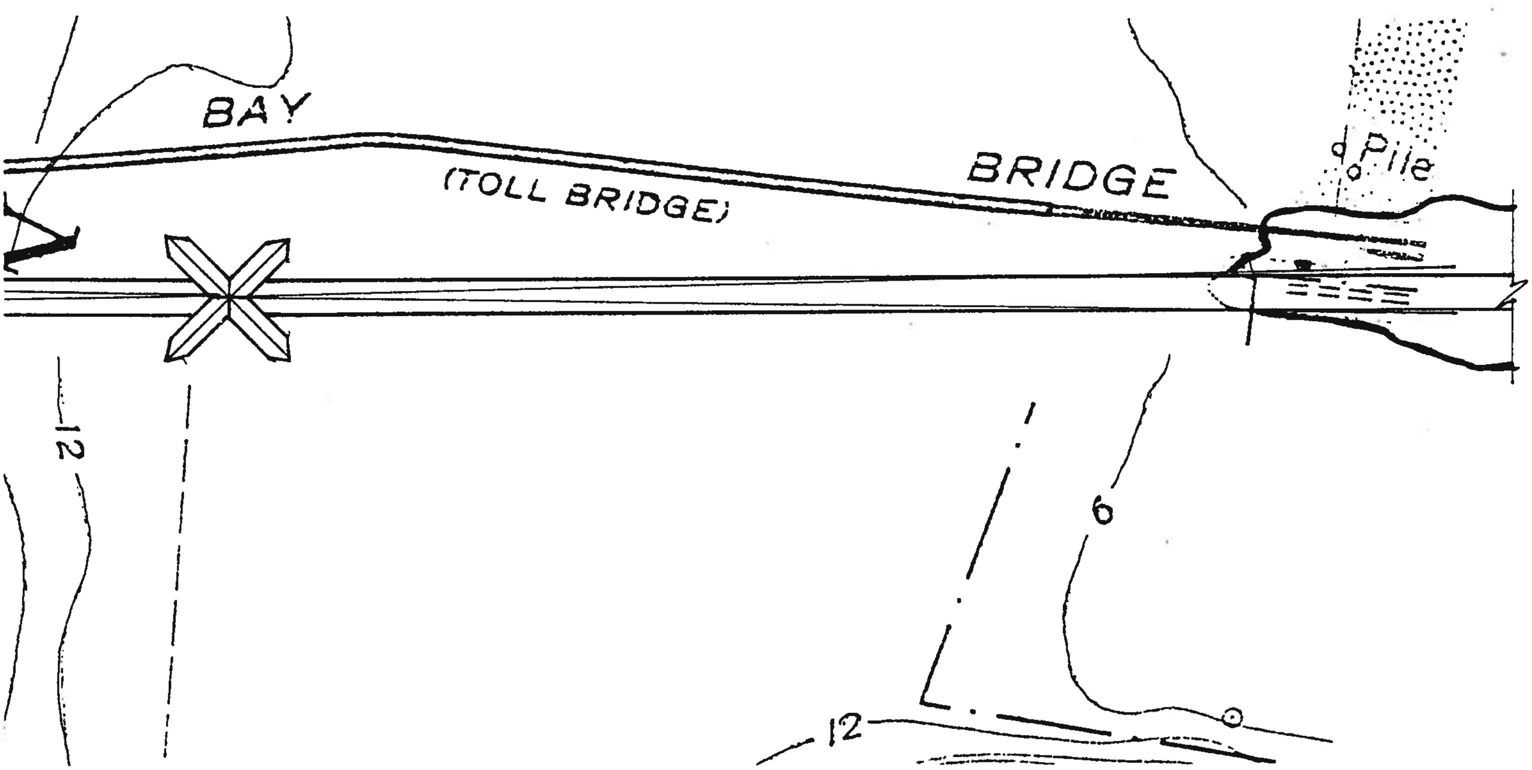
SOUTH ELE



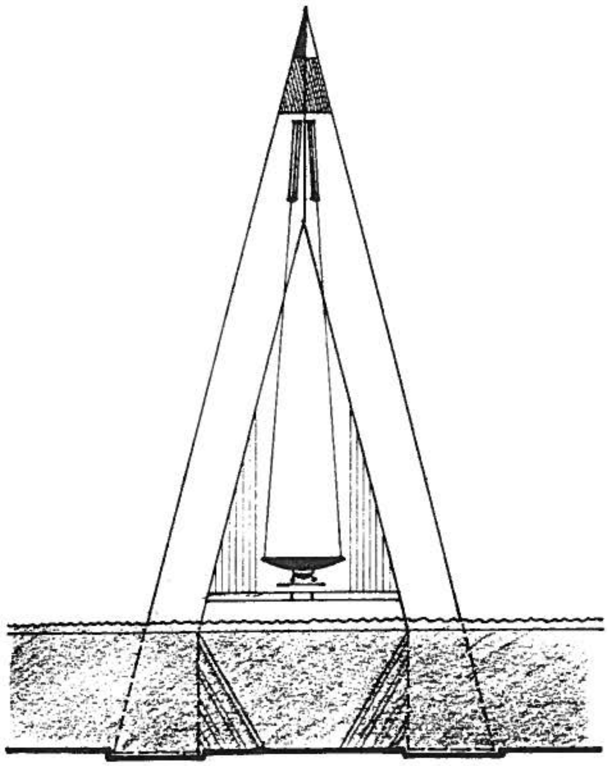
SITE PLA



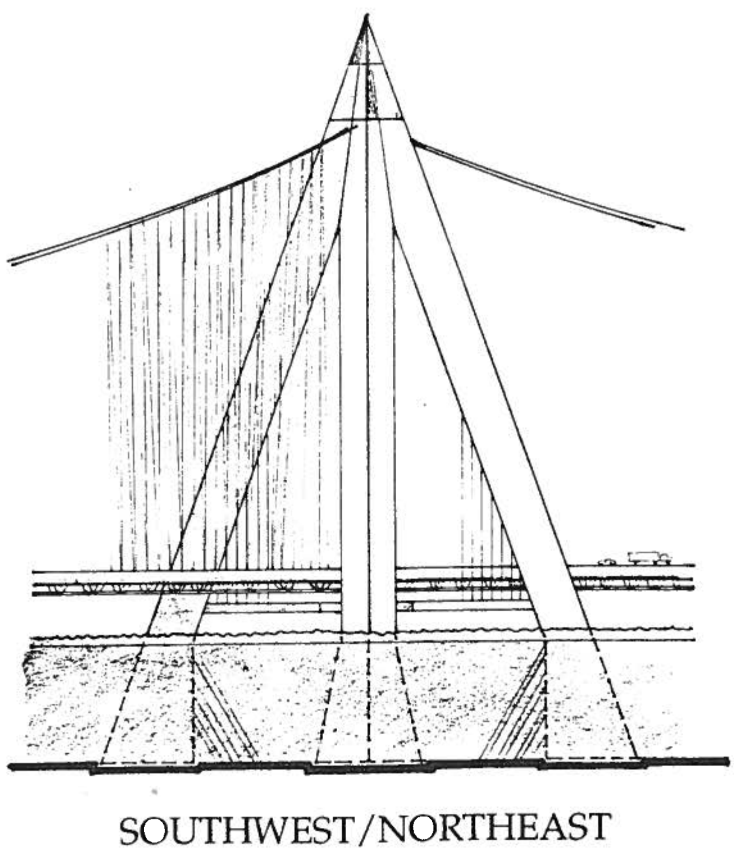
ATION—1:10,000



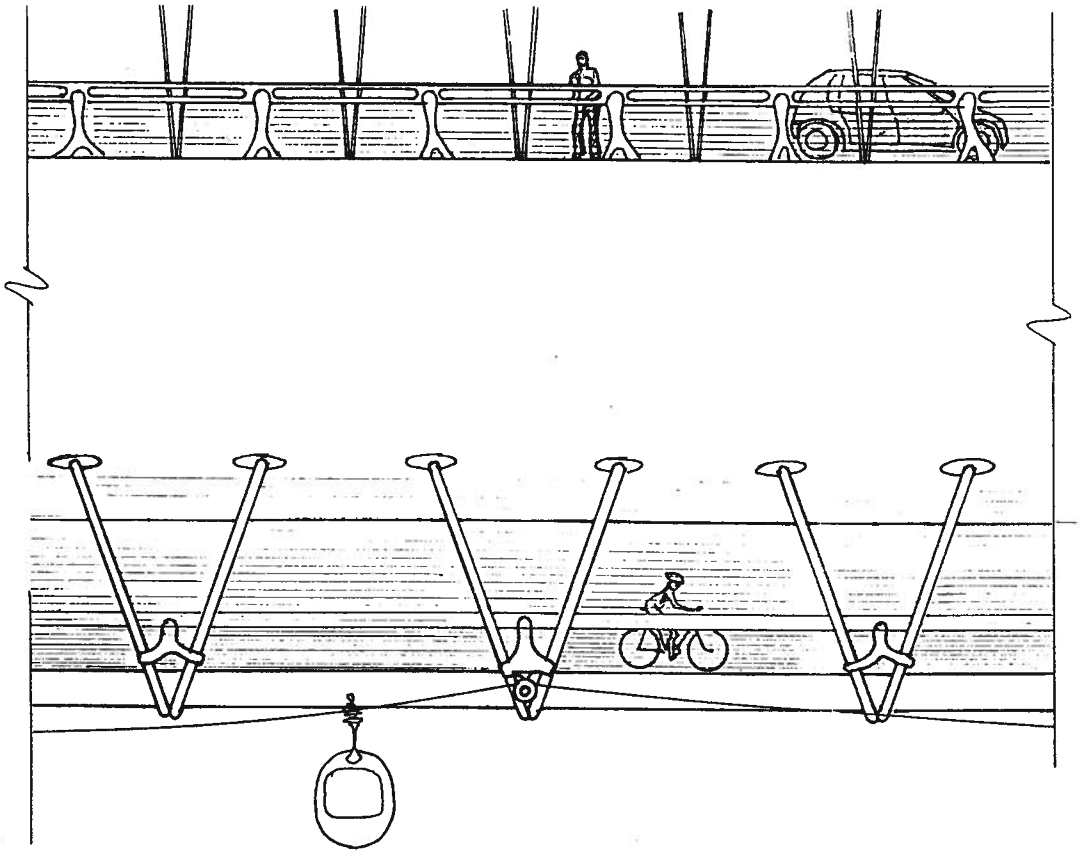
—1:10,000



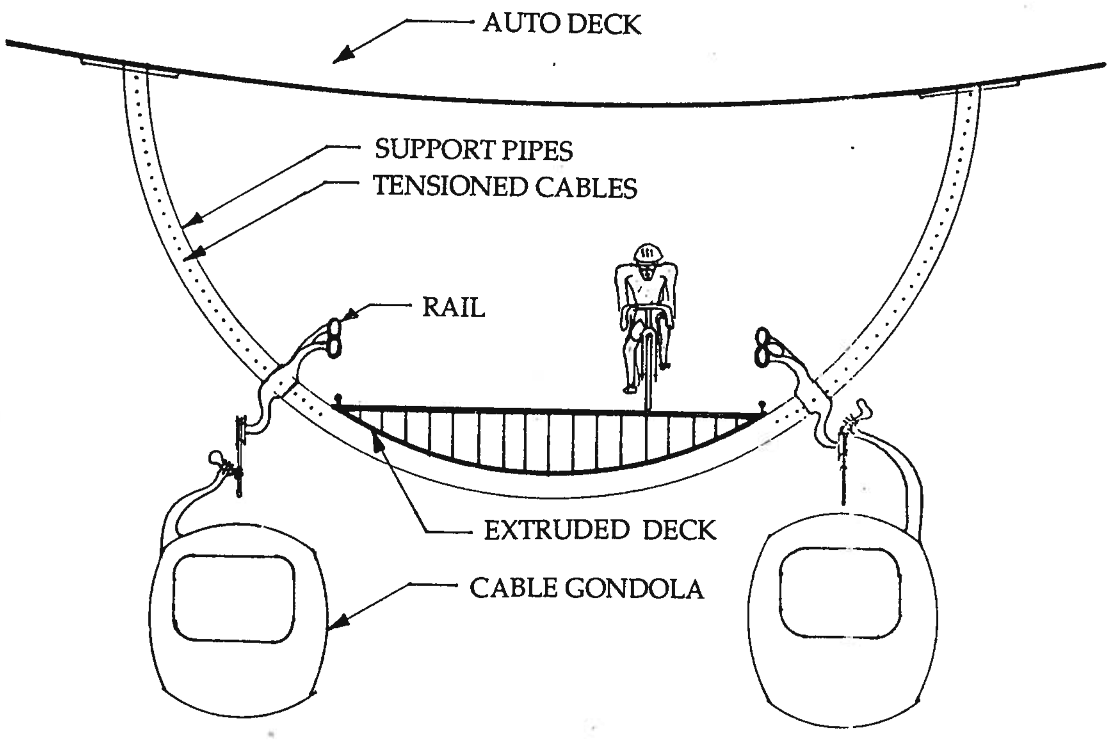
EAST/WEST ELEVATION
DECK CROSS SECTION



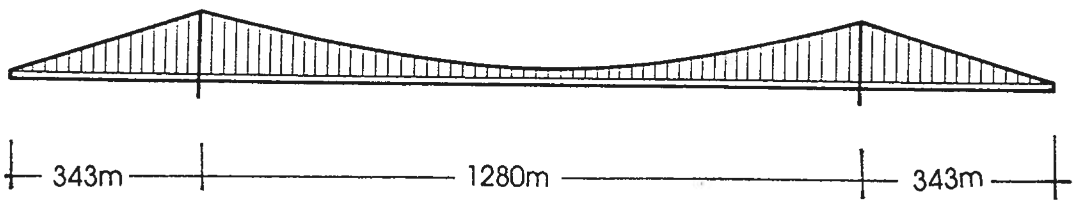
SOUTHWEST/NORTHEAST
ELEVATION



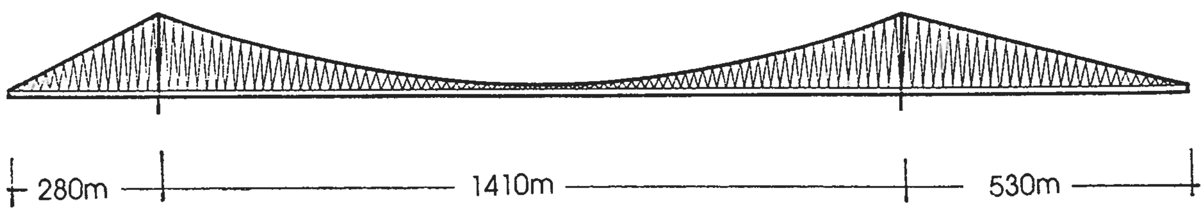
BRIDGE DECK PARTIAL ELEVATION



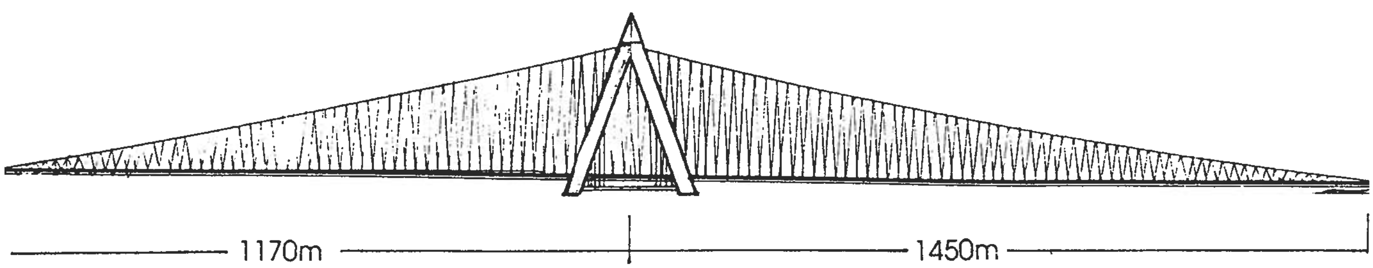
BICYCLE PATH CROSS SECTION



GOLDEN GATE BRIDGE



HUMBER BRIDGE



SAN FRANCISCO-OAKLAND BAY BRIDGE

COMAN
FEHER
ASSOCIATES

401 39th Street Sacramento, CA 95816 (916) 731-8880 fax: (916) 739-6951