Ben C. Gerwick, Inc. has specialized in the concept development and construction of major marine structures since the 1920's, first as a heavy construction company and since 1971 as consulting engineers. Ben C. Gerwick, Inc. has since 1988 been affiliated with COWIconsult, a leading Danish consulting engineering firm with a staff of more than 1300.

Ben C. Gerwick, lnc.'s worldwide experience includes:

- Marine Structures

Offshore Platforms (Arctic and North Sea)
Bridge Piers (US, Europe, Middle East and Asia)
Wharves and Piers (US, Australia, Asia, the Middle East and South America)
Outfalls (US and Asia) Floating Structures (US)

- Marine Concrete Technology

Durability
Tremie Concrete

- Foundation Technology

Caissons
Large Diameter Piles
Drilling
Pile Driving

The services provided include:

- Concept Development

- Value Engineering

- Expert Evaluation

Accident Investigation
Rehabilitation
Peer Reviews
Trouble Shooting

- Design Criteria Development

Ice Forces

Ship Collisions

- Constructibility Analysis

Construction Planning

Construction Engineering

- Design

Drawings

Specifications

Ben C. Gerwick, Inc. today comprise a staff of 13, of which 11 are engineers in addition to a number of associated part-time specialists.

Ben C. Gerwick, Inc. clients encompass both the public and private sector. The oil industry provided the bulk of the work in the 70's and 80's with the large projects in the North Sea and the Arctic areas. The ports along the West Coast of North America created major activity on extensions and deepenings of facilities to cater for the increased container traffic.

Ben C. Gerwick, Inc. has lately been engaged by a number of large consulting engineering companies and contractors for specialist consultancy assignments. Services in connection with earthquake retrofitting of structures has been sharply increased since the Loma Prieta Earthquake in October, 1989, both for port authorities and Caltrans. Other client groups include international financial institutions (particularly the World Bank), railway authorities, Army Corps of Engineers, US Navy and Coast Guard.

During the last few years, four main groups of assignments have been focused upon by Ben C. Gerwick, Inc:

- Offshore Concepts for the Arctic Areas
- Heavy Bridge Foundations
- Ports, Wharves and Piers
- Rehabilitation Works

The offshore concepts have concentrated on Gravity Base Structures for the Canadian areas in the Beaufort Sea (15-20 m water depths) and Newfoundland (80 m water depth and collision risks with large icebergs). Ben C. Gerwick, Inc. has had continued activity on the Jamuna (Brahmaputra) River Bridge in Bangladesh. On the Fixed Link across the Great Belt in Denmark, Ben C. Gerwick, Inc. has been involved with special tasks on concrete durability of the precast concrete tunnel liners, the caisson foundations on the West Bridge and the pylon and anchor block foundations for the suspension bridge across the Eastern Channel. This latter will be the largest in the world by the time it is built. Ben C. Gerwick, Inc. was engaged in the concept development of the foundations for the new milelong Martinez-Benicia Bridge for four alternate superstructure types. Ben C. Gerwick, lnc.'s work on the port facilities has lately been totally dominated by earthquake repair and retrofit. The Port of Oakland experienced major damage to batter pile supported wharves that failed in brittle shear. The repair and upgrading work has utilized the concept of vertical piles incorporated into ductile frames and the provision of flexibility during major earthquakes.

Ben C. Gerwick, Inc. expects increased future activity on earthquake retrofitting, partly on wharves and piers along the Californian coastline and on the many freeway bridges in need of retrofit and upgrading. Increased activity is also anticipated on the newly authorized major bridges in the San Francisco Bay which are designed to alleviate the ever increasing traffic in the Bay area.

In order to accommodate increased staff and to provide more efficient activities Ben C. Gerwick, Inc. moved offices to 601 Montgomery Street, Suite 1400, just two blocks away from the former location in San Francisco.

Ben C Gerwick, Inc. new

office location at

601 Montgomery Street, 4th floor

San Francisco.

The October 17, 1989 earthquake in Northern California caused severe damage to many of the pile supported wharves at the Port of Oakland. The Port of Oakland occupies 19 miles of the mainland shore of San Francisco Bay, one of the finest natural harbors in the world. There are more than 550 acres of marine terminal facilities, 28 deep water berths and 27 container cranes, including 7 of the post Panamax type. On dock covered storage space exceeds 600,000 square feet.

Ben C. Gerwick, Inc. was selected by the Port of Oakland to inspect, evaluate and design the structural repairs for the following facilities:

- 7th Street Terminal: Berths 35-38 (Public Container Terminal)
- Berths 10, 20, 21, 69, 83 & 84

- Carnation Terminal (Upgrading of design)

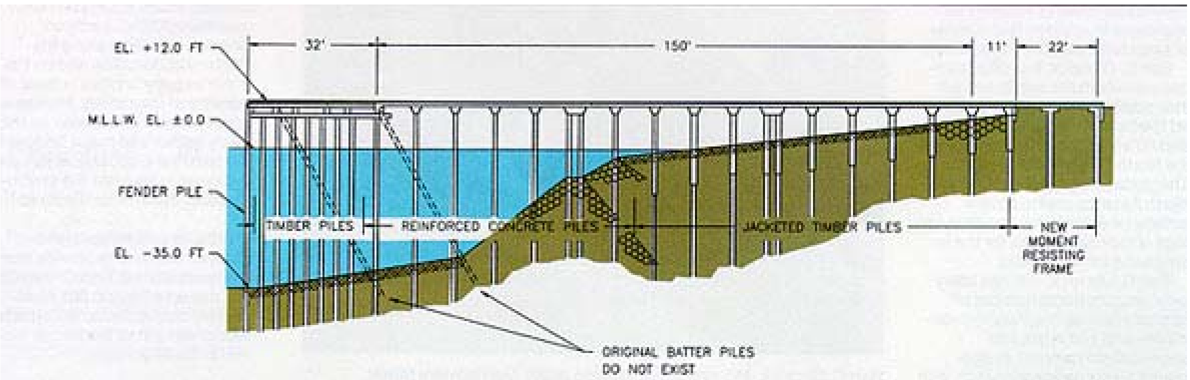
The most severe damage took place at the 7th Street Terminal. The site was reclaimed from the Bay by filling operations in the mid-1960's at the time of the BART system construction. Water depth at the site before reclamation varied from about 15 to 30 feet. 5 to 10 feet of soft Bay Mud deposits were present below the mudline and underlain by medium dense to dense sand. After removal of Bay Mud dredged sand fill was placed by bottom dump barges behind rock toe dikes. Fill materials placed in the terminal areas behind the perimeter dike included hydraulic sand fill and engineered fill above water.

7th Street Terminal rehabilitation works.

Soil liquefaction in backland storage areas behind the wharves causing settlements of up to one foot took place, incapacitating landside crane rails supported on spread footings and contributing to damage to many batter piles, that failed in brittle shear partly as a result of insufficient confinement reinforcement.

It was decided to replace all batter piles with new vertical piles that could be incorporated into a new ductile, moment-resisting frame, offer safe new foundation for the landside crane rail and contribute to the development of a longer natural period of the entire structure, which will decrease future seismic response. The retrofitting involved the removal of a 13 ft. wide strip of the concrete slab that included all batter piles. It was replaced with a 30 ft. wide deck supported on two rows of 24 in. vertical prestressed concrete piles. The remaining wharf structure was then connected to this new ductile moment-resisting frame by extending deck reinforcement directly into the slab of the new frame structure. Future liquefaction of the dike section is prevented by installing stone columns - using vibro replacement - to compact the loose soils to depths up to 45 ft. The sandy soils are densified beyond the threshold liquefiable density, and columns of dense crushed stone reinforce the soil mass and provide drainage of soil pore water pressures during seismic shaking. Previous problems with loss of backfill material from behind the existing wharf structures during changing tides will be prevented by the construction of a driven sheet pile wall down to elevation - 5 ft.

The Port of Oakland required completion of the first 300 ft. of wharf in 60 days, including the design period, to meet the scheduled delivery of two new container cranes. The repair design for the remaining 2,500 ft. was completed in 3 months.



Typical cross-section of

Berth 69 looking south.

To ensure consistency of future designs of repair works the Port of Oakland has updated and eff icially adopted their standard wharf design criteria to include many of the new concepts developed during the design of the Berth 26 wharf. The earthquake repair work for the 7th Street Terminal incorporated these concepts. Some of the important criteria are:

- Wharves shall be designed as ductile moment resisting frames supported by vertically driven piles. No batter piles shall be used.
- Both crane rails shall be pile supported and shall be connec' edhorizontallybycontinuous wharf deck to control the gage of the rails.
- A cutoff wall of sufficient depth shall be constructed along the back of the wharf to prevent erosion of yard materials by tidal wave or other action under the wharf.

The work on berths 10, 20, 21, 69, 83 and 84 originating as far back as the 1920's is presently ongoing. The work follows an agreed sequence in consultation with the Port of Oakland:

- Conduct inspection
- Review original design and design criteria and compare with current operations and code requirements.
- Develop appropriate repair methods and prepare cost estimates
- Evaluate costs of structure repairs with remaining life of structures
- Prepare final report with priority ranking of repairs and replacements

- The original design for the Carnation Terminal was prepared in 1986 and included three wharf segments. Segment 3 was constructed in 1988 under the designation Berth 26. Segment 2 under the designation Berth 30, is planned for construction in 1991 and Ben C. Gerwick, Inc. in cooperation with F. E. Jordan Associates has initiated a design upgrade to revise the project to meet the new wharf design criteria. The work will include:

- Study addition of railroad track to wharf
- Design planstbasic update
- Construction methods
- Specifications, cost estimates and schedules
- Land disposal of dredge material
- Bid and construction support

Construction of the Great Belt Link in Denmark is one of the largest transportation projects under implementation in Europe. The Great Belt Link will be the first fixed east-west transportation connection in Denmark. The construction of the Great Belt Link is also the first major step towards a general improvement of the northern European transportation network, which is expected further developed by the construction of more fixed links (between Denmark and Sweden and between Denmark and Germany).

The Great Belt Fixed Link include three major construction projects:

- A 7.9 km long bored (TBM driven) railway tunnel comprising 7.7 m diameter separate tubes for trains in each direction. Cross passages are provided at 250 m intervals for mechanical and electrical equipment and escape routes. The main tunnels will be lined with 400mm thick segmental reinforced concrete linings, each measuring approx. 33m x 1.5m.

- A 6.6 km long railway and 4-lane freeway bridge. The road and railway girders are constructed in precast, prestressed concrete in different width and depth. Span lengths are 110m. The bridge spans and substructures will be cast in a prefabrication yard and erected by a U-shaped crane vessel with a lifting capacity of 6,000t. 310 units of foundation caissons, pier shafts and bridge girders wil I be placed.

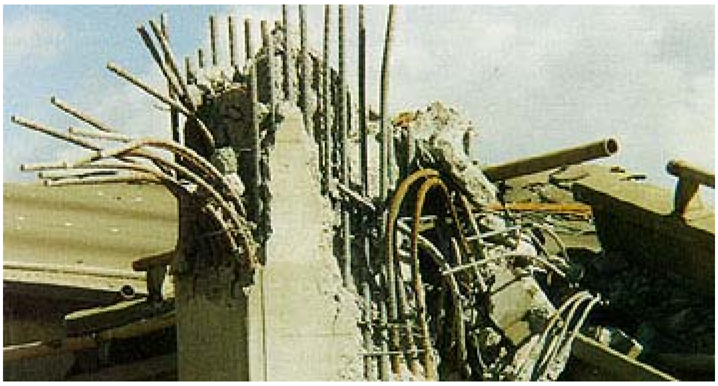
- A 6.8 km long 4-lane freeway bridge with a suspension span of 1.7 km. For comparison the Golden Gate Bridge has a suspension span of 1.3 km. The bridge girder is designed as an aerodynamically shaped, closed steel box girder with orthotropic steel deck. The 230m high pylons for the suspension span will act as concrete frames supported on a cellular gravity based pier. The anchor blocks for the main cable are large cellular sandfilled caissons placed on a crushed stone bed.

Prefabrication plant for

tunnel lining segments.

COWIconsult -to whom Ben C. Gerwick, Inc. has been affiliated since 1988 is the lead consultant in various joint venture combinations for all three construction projects. Apart from the traditional engineering disciplines for such major undertaking COWiconsult was engaged to undertake studies related to marine environment studies, development of traffic model and risk assessment studies including overall, operational, ship collision, and construction risk analysis. Ben C. Gerwick, Inc. participated in the ship collision study with procurement of US data and experience related to ship collision risks and preventive systems such as VTS. In addition Ben C. Gerwick, Inc. was engaged with studies related to concrete durability for the precast concrete tunnel liners, the caisson foundations for the 6.6 km long railway/freeway bridge (West Bridge), and the pylon and anchor block foundations for.the suspension bridge (Eastern Bridge). Dense high quality concrete is essential for the tunnel liner segments due to the high groundwater chloride and sulphate levels (80 m hydrostatic pressure at tunnel center). Four barriers against chloride penetration were included in the project:

- Annular grout filling between the lining and the soil
- Concrete composition including flash, micro silica and OPC with a WN-ratio of max. 0.35
- Epoxy coated reinforcement
- The possibility of providing cathodic protection if corrosion should occur some time in the future



Western Bridge prefabrication yard.

The overall concept for the Western Bridge has been based on prefabrication. The prefabrication yard is located near the site and has six production lines, e.g. double lines for superstructure girders, foundation caissons and pier shafts. The foundation caissons comprise a cellular base (with open top) and a shaft capped by a 2 m thick plinth to receive the pier shafts. All caissons have identical grid dimensions at the base to enhance industrialized production based on slipforming. The cantilevering portion of the bottom plate can be varied to provide foundation areas as required. The pylons and anchor blocks for the Eastern Bridge will be of spectacular size. The 230 m high pylons are designed as concrete frames with slightly inclined variable cross section legs and a concrete cross beam at the top. The foundation is a cellular gravity based pier to be constructed using off-shore GBS concepts. The anchor blocks are large cellular sandfilled caissons placed on a bed prepared of crushed stone. Both insitu construction behind temporary dikes and precasting ashore of the anchor blocks has been developed for bidding by contractors.

The construction works were initiated for the tunnel in 1988 while the Western Bridge contract was let in the summer of 1989. The tenders for the Eastern Bridge are expected at the end of 1990.

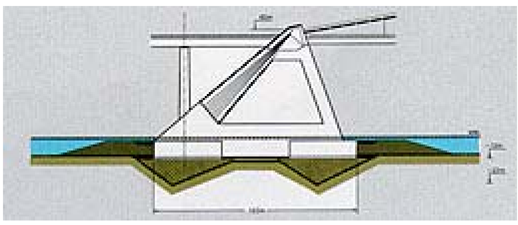
Planned opening dates are:

- Railway connection

April 1, 1993

- Road Connection

April 1, 1996



Eastern Bridge. Longitudinal section of anchor block.

Since the 70's, Ben C. Gerwick,Inc. has been continuously involved in concept, and project developments for Gravity Base Structures, GBS, for the Arctic, and other ice infested waters. Most recently, Ben C. Gerwick, Inc. has been engaged in the development, and refinement, of several advanced concepts for GBS platforms in the Canadian and U.S. Beaufort Sea, as well as the U.S. Chukchi Sea:

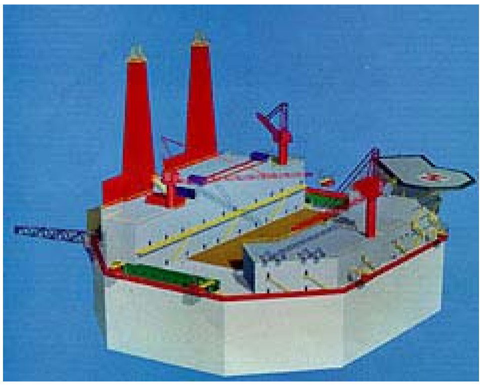
- Optimization of the proposed Amauligak platform for Gulf Canada.

- Development of conceptual doubleshelled conical exploratory and production GBS platforms for a joint petroleum industry group.

- Development of conceptual seafloor penetrating, exploratory and production, GBS platforms incorporating a proprietary configuration for a major oil company.

Amauligak is located 37 miles (60 km) from shore in 105 ft. (32m) of water. The discovery well for the field was drilled in 1984, and it is believed that the Amauligak field is large enough to serve as a lead project which would allow for the construction of a pipeline down the Mackenzie Valley, which would in turn allow for the development of other proven fields in the Mackenzie Delta. The Amauligak

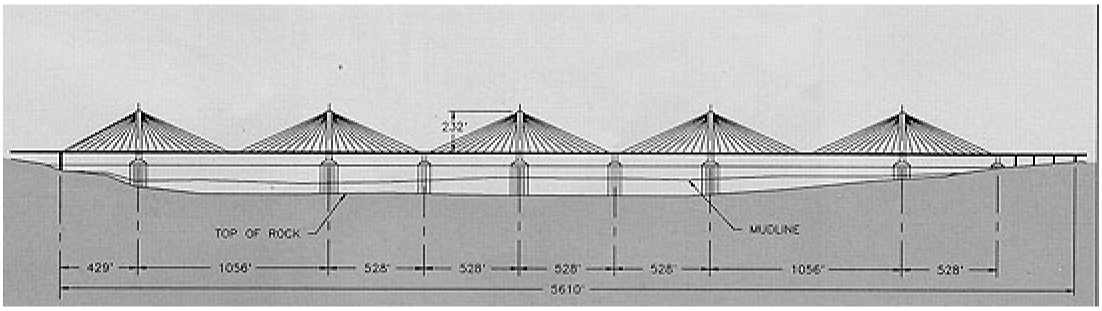
Production Platform is currently planned as a sand-cored structure, with a setdown depth of 52.5 ft. (16 m), resting on a submerged sand berm. The densified sand-core of the platform is an economic manner to gain both topside working area, and additional weight to resist potential sliding of the platform induced by ice loading. It is proposed to construct the GBS in four self-floating segments that would be joined afloat intemperate latitudes and towed to the North with an empty core-area, which would be infilled with sand after installation. The substructure for the Amauligak platform would either be of reinforced concrete, or steel/concrete/steel sandwich composite, construction.



Artist rendering of the Amauligak platform

The double-shell conical GBS concept was developed for service in relatively deep water in the U.S. Beaufort and Chukchi Seas. Design ice features in these areas include multi-year ridges with thickness of up to 80 ft. (24.4 m). Conically shaped GBS structures resist such large ice features by breaking them in upward flexure against the sloped peripheral wall of the structure. Such structures require large foundation areas to resist potential ice induced sliding and overturning. By utilization of a double-shell configuration the GBS can be designed to have adequate strength to resist concentrated ice forces, while minimizing material volume and cost.

A parallel crossing of the Carquinez Strait in Northern California adjacent to the existing Benicia-Martinez Bridge is planned by Caltrans. The bridge will be placed on State Route 680 in Contra Costa and Solano County. The new bridge is a high level crossing like the existing bridge and located in a high seismic zone. It will be 5600 ft. long and a minimum 135 ft. above the water at the channel to provide clearance for shipping in the Sacramento River. The proposed new Benicia-Martinez Bridge Project consists of constructing a second 5-lane bridge with shoulders. The new bridge will be wider and will be designed for a higher seismicity.



Longitudinal section of cable-stayed alternate.

Caltrans initiated in 1989 preliminary engineering studies and cost estimates for 4 different concepts:

- Steel trusses, concrete deck, 528 ft. spans (as existing bridge)
- Steel box girders, orthotopic deck, 528 ft. spans
- Concrete segmental box girders, 528ft.spans
- Cable stayed girders in steel/concrete, 528/1056 ft. spans

Caltrans selected 3 different major consulting organizations to develop alternates and Ben C. Gerwick, Inc. was selected to undertake the investigations for the foundation concepts.

The river at the bridge site ranges up to 60 ft. in depth and is underlaid by mud varying from 50 to 85 ft. deep. Below this is firm foundation rock. The hydrology at the site is complex. Two major rivers of the Central Valley converge to form the Carquinez Straits. Depending upon the flow in the Strait and tidal conditions of the bay, severe scouring and/or siltation can occur in the area. The installation of additional caissons in the Straits may further increase the scour potential and the effect on the existing piers must be considered. To ensure consistency of the designs of the various alternates being studied, a

Uniform Design Criteria was developed by Caltrans. In particular it was stated that preliminary designs should be based on an equivalent static force analysis using a minimum ARS/Z factor of 20%.

The initial considerations on applicable foundation concepts for the new bridge included:

Steel cylinder caissons

Prestressed concrete cylinder caissons

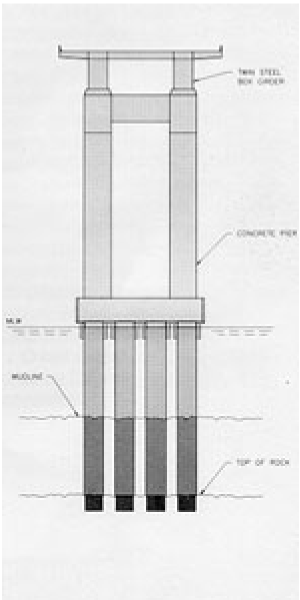
Bell pier concept

Float-in-box caisson

Prestressed concrete cylinder piles

Each of the candidate foundations was analyzed for ease of constructibility and risk, construction personnel and equipment required, temporary structures needed and time of construction.

Two basic foundation types were finally selected. The first calls for a floating box caisson, similar to that used for the existing bridge. The box would be precast in a protected fabrication yard, floated into place and then anchored into position. Steel caissons would then be lowered through openings in the footing bottom, the mud, sand and gravel removed from the interior, and the caisson shell seated on the rock. A socket would then be drilled 10 ft. into the rock, a reinforcing cage placed in the socket and the socket, steel caisson and compartment of the box caisson filled with concrete.



Cross section of steel box girder alternate.

The alternate concept, which turned out to be cheaper, calls for the steel caissons installed in a similar manner, but prefabricated forms and side forms would be used to cast the footing above water level. A moment connection would be developed at the footing/caisson interface by extension of caisson reinforcement into the footing to resist the high lateral seismic loads.

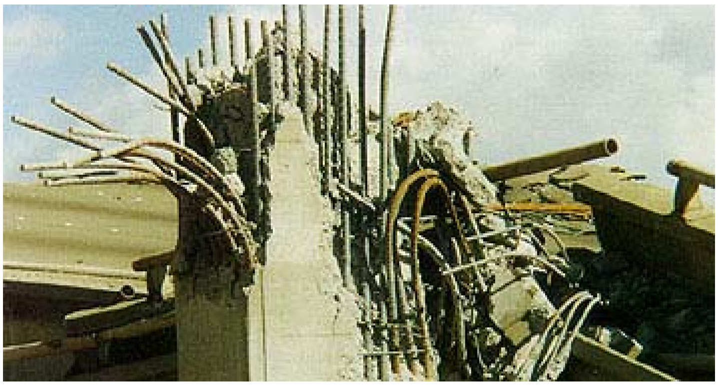
Both concepts employ a new development of composite steelconcrete caissons. These cylinder piles are designed so that the concrete core carries the preponderance of the axial load, while the steel carries majority of the bending. The resultant pile has high ductility. The concrete responds to combined axial load and bending in a state of multi-axial stress, while the steel is restrained from local buckling. Shear transfer is attained by studs, welded rebar or shear lugs. The result is a substantial reduction in caisson wall thickness and often some reduction in required diameter. The concrete fill in the caisson is placed by the tremie process, using carefully controlled mix and methods so as to minimize bleed and shrinkage, and prevent excessive heat of hydration. The result of this use of composite steel and concrete is high capacity with significant ductility and robustness both under ship collision or earthquake.

For this selected substructure foundation a detailed cost estimate was prepared based on the quantities developed during the preliminary design. Cost estimates were based on the construction costs for the current year including contractor's mark up for overhead and profit. Caltrans added estimates for fender systems, approach spans, operational facilities, and maintenance facilities.

The detailed preliminary study will be used by Caltrans to evaluate and select the appropriate design alternatives so that final design can-proceed on the project, most probably with two alternate superstructure concepts in 1991.

Part of Ben C. Gerwick, Inc's continuing participation for restoring major civil engineering structures damaged by the Loma Prieta Earthquake is its activity in the design of retrofitting concepts for the State of California, Department of Transportation (Caltrans), Route 1-280, double and single deck freeway structures, located in the south east corridor in the City and County of San Francisco.

Ben C. Gerwick, Inc. is a subconsultant to CH2M-Hill, the primary party contracted to Caltrans for a number of retrofitting projects in the State. Approximately 8,000 bridges will be investigated for possible retrofitting and over 30 consulting firms has been or will be selected by Caltrans to undertake this work. The CH2M-Hill team is one of the selected consultants. The 1-280 project is one of the priority contracts identified for retrofitting.



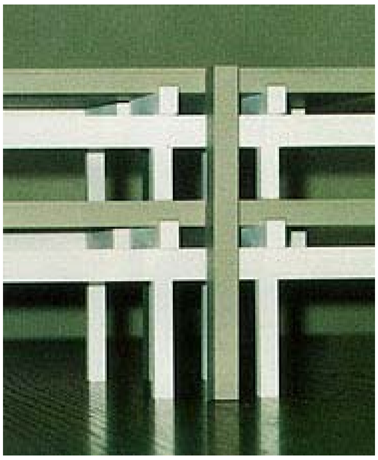
Shear failure of Cypress Double Deck Freeway

Two design sub-projects have been assigned to Ben C. Gerwick, Inc., they are:

- A generic retrofit design for a two deck, elevated freeway structure, and
- A specific single deck structure.

In the generic design, CH2M-Hill advocated a "Superframe", a concept which works well with many of the specific I-280 project structures. It was also decided to evaluate this concept for a generic or general solution for the remaining portions of I-280.

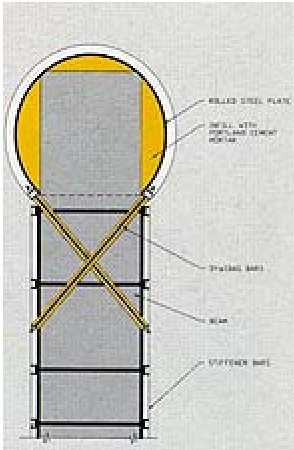
The Superframe is an auxiliary steel frame which supports the existing structure, similar to falsework, so that any structural failure caused by a future seismic event would result in load transfer from the existing structure to the Superframe. The Superframe would be able to carry the entire weight of the existing structure, if necessary.



Model of Superframe concept.

The applied lateral load was 37.5 percent of the combined structures; i.e. the existing structure and the Superframe. The Superframe provides sufficient stiffness to limit story drift to 2 inches and control maximum stresses to not greater than yield point assuming a "stand alone" structure, that is, a structure unrestrained by boundary conditions.

The general design basis for seismic loads in the structures is 25 percent lateral load and ARS (acceleration response spectra) loads. The first case is referred to as the "strength level" case and its criteria is basically the same as the generic design. Often this case governs the ultimate outcome of the final design because design stresses are controlled to be within the elastic properties of the materials. The second case may be referred to as the "ductility level" case for which recognition is given to the inelastic behavior of the structure. The ductility level design must resist the maximum credible earthquake expressed in terms of the ARS curves. In order to simplify the design, modal analyses are performed assuming elastic behavior of the structure and the principle of superposition applies. Ten modes are required to capture at least 90 percent of the effective force. Initially, the results of modal analyses are modified by ductility factors which represent the type of structure designed, in this case, a moment resisting frame. The final analyses includes modal analyses in which the structure is degraded by plastic hinging of critical joints which introduces its inelastic response characteristics.



Column retrofit to increase confinement with steel shell.

Other concepts are being studied by Caltrans and their other consultants.