Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 73/1/73/2 (1995)

Artikel: Extending the lifespan of the North Anchorage Housing of the Golden Gate Bridge

Autor: Bernstein, Fay / O'Sullivan, Michael / Cao, Jerry

DOI: https://doi.org/10.5169/seals-55203

Extending the Lifespan of the North Anchorage Housing of the Golden Gate Bridge

Prolongement de la durée de vie de l'ancrage nord du pont de Golden Gate

Verlängerung der Gebrauchsdauer der nördlichen Seilverankerung der Golden-Gate-Brücke

Fay BERNSTEIN
Principal
Faye Bernstein & Assoc.
San Francisco, CA, USA

Faye Bernstein received her architectural engineering degree from the Univ. of Miami, Florida. She has over 25 years of structural engineering experience on major projects including bridges, industrial facilities, high-rise buildings and historic landmark structures. She has been principal of Faye Bernstein and Associates for 11 years.

Michael O'SULLIVAN
Engineering Manager
Faye Bernstein & Assoc.
San Francisco, CA, USA

Michael O'Sullivan received his B.S. and M. Eng. degrees from the University of California, Berkeley. He has over 20 years of Structural Engineering experience on a wide variety of major projects including bridges, marine, heavy construction, both fixed and floating offshore oil platforms, industrial facilities and buildings.

Jerry CAO
Senior Civil Engineer
Golden Gate Bridge District
San Francisco, CA, USA

Jerry Cao received his B.S.C.E. degree from National Taiwan Univ., and M.S.C.E. and Ph.D. degrees from Univ. of Notre Dame, Indiana. He is a Project Engineer on the Golden Gate Bridge Seismic Retrofit Project, responsible for project coordination of the suspension spans and north structures.

SUMMARY

The retrofit process of the North Anchorage Housing began with the study of five structural systems. In addition to the design criteria, several other design constraints were imposed: preserving the historic character, providing an open corridor for a future light rail system, and maintaining continual service of the bridge. The final design provides new lateral and vertical support for the structure within the existing housing shell and includes a new roadway deck. By incorporating the new deck into the seismic retrofit of the Housing, significant savings were realized in the cost of the retrofit work.

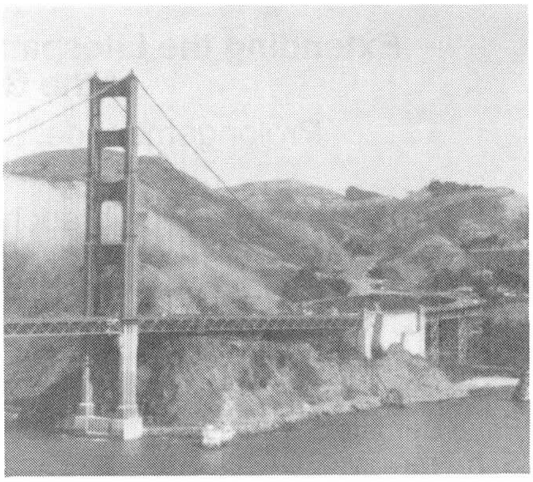
RÉSUMÉ

Le processus de consolidation de l'ancrage nord a débuté par l'étude de cinq systèmes structuraux. Outres les critères de projet, plusieurs autres contraintes étaient imposées, préserver le caractère historique, garder un espace libre pour un futur système léger de transport ferroviaire et maintenir le pont en service pendant les travaux. Le projet final prévoit un support latéral et vertical pour la structure à l'intérieur de l'ancrage actuel et comprend un nouveau tablier routier. En réalisant le nouveau tablier en même temps que la consolidation parasismique de l'ancrage, des économies importantes ont été réalisées dans l'ensemble des travaux de consolidation.

ZUSAMMENFASSUNG

Bei der Ertüchtigung des nördlichen Seilverankerungsblocks waren neben den Bemessungskriterien etliche andere Randbedingungen zu beachten: der historische Charakter des Bauwerks, die Freihaltung eines Korridors für eine zukünftige Leichtschnellbahn und das Bauen unter Verkehr. Von fünf untersuchten Tragsystemen wurde eines gewählt, das innerhalb der bestehenden Hülle zusätzliche seitliche und vertikale Stützung verleiht und eine neue Fahrbahnplatte beinhaltet. Dadurch konnten bedeutende Einsparungen bei der Sanierung realisiert werden.

1.0 BACKGROUND



The North Anchorage Housing is located on the side of a mountain on the Marin side of the bridge's main span. Uphill on the west side lie the Marin headlands of the Golden Gate; downhill on the east side is the shore of the San Francisco Bay. Functionally the housing encloses and protects the main bridge cables where the cable strands splay out to their attachment to mass concrete anchor blocks. In addition, its roof forms the highway roadbed between the north end of the suspension bridge and the north viaduct structure. In contrast to the lightness of the steel main span, the housing is a massive-looking reinforced concrete building-type structure, measuring 107 meters long and 40 meters wide. Its height varies from 18 to 34 meters due to the sloping site on which it is located. Interior support for the roadway is provided by a series of reinforced concrete bent frames in the transverse direction. Perimeter walls of the housing as well as the roadway and walkways are of reinforced concrete construction. The roadway and walkway deck consist of a simple span system of longitudinal stringers with integral slab spanning 7.6 meters between transverse frames. The south side of the housing is supported on spread footings which bear on native rock, while the north is supported on the anchor blocks. The anchor blocks, in turn, are founded on and keyed into the native rock.

2.0 RETROFIT APPROACH

A state of the art seismic retrofit is being performed on the bridge and a project specific retrofit criteria has been developed. The site specific response spectrum shown in figure 1 is being used for the retrofit with a demand/capacity analysis similar to current AASHTO requirements.

A number of retrofit options and structural systems were studied for the anchorage housing and were evaluated on the basis of technical merit and cost. These options included:

- A) Base Isolation
- B) Ductile Concrete Frames
- C) Concrete Shearwalls
- D) Hybrid Systems

Initially all of these options considered retrofitting the existing housing and maintaining the concrete deck.

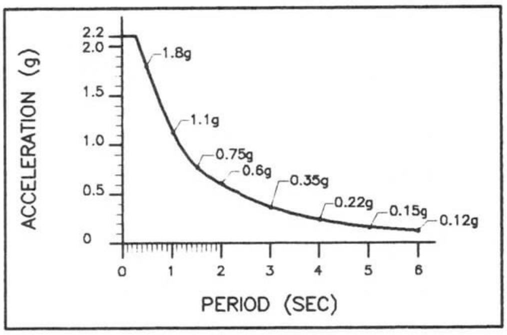


FIGURE 1

3.0 DESIGN CONSTRAINTS

Three major design constraints were imposed on the designer of the retrofit system. First, because of the historic character and appearance of the bridge, the exterior appearance of the housing could not be altered by the structural retrofit work. While appearance was a major constraint, the project criteria required, however, that seismic safety not be compromised. Second, the project criteria requires that the bridge remain serviceable after a maximum credible seismic event with little or minor repairable damage. As a result of this second constraint, combined with the location of the housing between two different structures, both with damping systems, seismic displacements had to be controlled and kept at manageable limits. The third constraint was to provide an open corridor beneath the roadway for a future light rail system.

BENTS ON NATIVE ROCK AT SOUTH SECTION

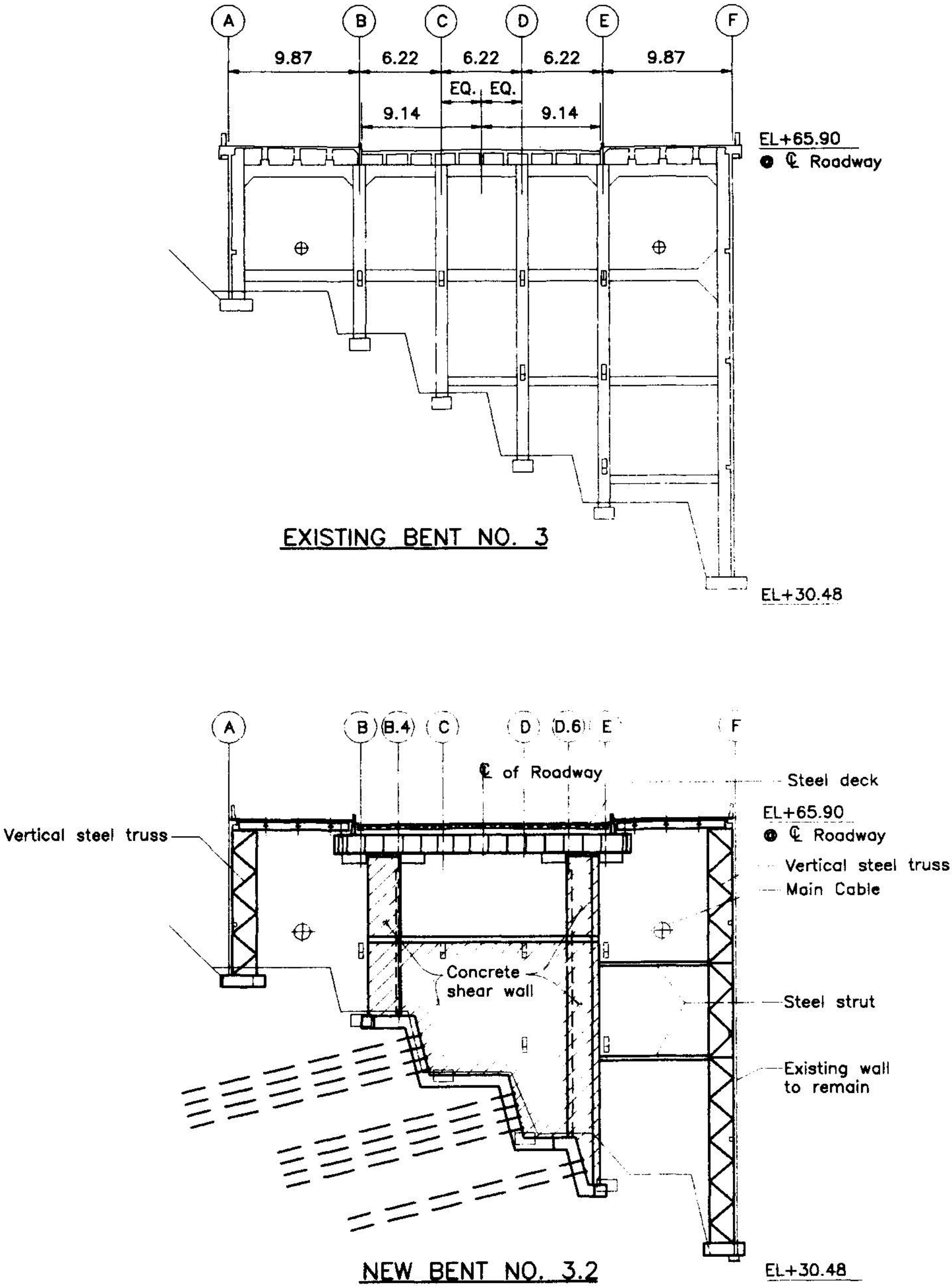


FIGURE 2

4.0 DESIGN CHALLENGE AND COMPLEXITY OF RETROFIT

At project start, retrofit of the housing appeared to require simple straight-forward modifications to a box type structure. But as the design process evolved, the housing retrofit became more complex. One reason for the complexity was the configuration of the housing. Vertical loads are supported on a series of transverse bents. The bents on the south end of the housing rest on the native rock while the ones on the north end are supported on the mass concrete anchor blocks. When the potential for rocking of the anchor blocks was identified, the housing retrofit required division of the housing into two distinct structures; north and south. The south end included the structure founded on native bedrock materials south of the anchor block region. The north end included the structure atop the anchor blocks. Since the east and west anchor blocks are not connected, they are free to rock independently under seismic excitation. As a result of this rocking potential, the north end was further divided into east and west structural sections. The structural separation was to be accomplished by providing new transverse roadway girders spanning between blocks, detailed to allow for differential movement.

Another reason for the complexity of the retrofit was the existing deck. The Bridge District had identified deck replacement as necessary but lacked available funds and understood that construction challenges made replacement impossible. The deck had been repaired several times but was not replaced when the bridge was redecked about 10 years ago. Modifications were performed in the 1950s and 1980s to resupport deck stringers which were cracking at their bearing locations. The modifications included installation of miscellaneous metal at every stringer and every bent. As a result of these repairs, the existing roadway stringers are now supported on a system of suspended bearings outward of the original bearings. In addition, a series of suspended access catwalks had been installed to allow inspection of the under roadway deck stringers. Working the retrofit around these obstacles proved very difficult. Further complexity of the retrofit was caused by the deck stringer expansion bearings which make the roadway deck discontinuous at 25 foot intervals. Numerous collectors, restrainers, and specialized details were required in the retrofit to provide a positive path for seismic forces and to control seismic displacements.

5.0 RETROFIT COSTS ALLOW FOR NEW VERTICAL SUPPORT AND DECK REPLACEMENT

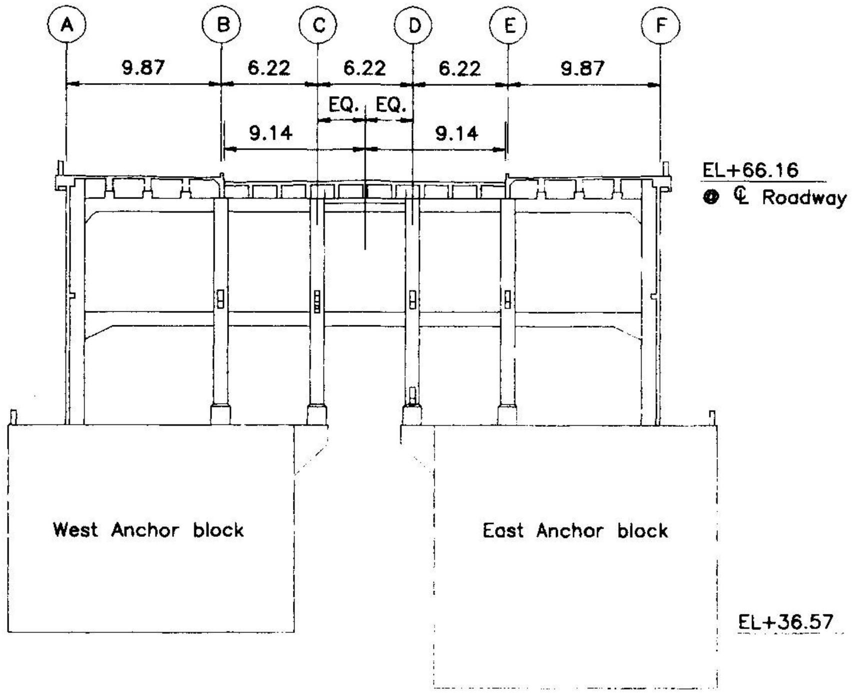
The original retrofit scope included strengthening of the housing to resist lateral loads. Vertical loads were carried by the existing bents and deck replacement was not included. When the potential for rocking of the anchor blocks was identified, it became necessary to replace the transverse deck girders above the anchor blocks. The retrofit concept was then modified to provide one structural system at the south portion of the housing and another in the north.

As the design continued to develop it became increasingly apparent that a high premium was being paid to retain the deck and work around the miscellaneous steel from previous repairs. The cost of deck replacement alone was previously prohibitive; but deck replacement in conjunction with the seismic upgrade of the housing became viable. However, the deck could only be replaced with a construction procedure which would allow use of all traffic lanes during daytime hours and would not increase construction costs.

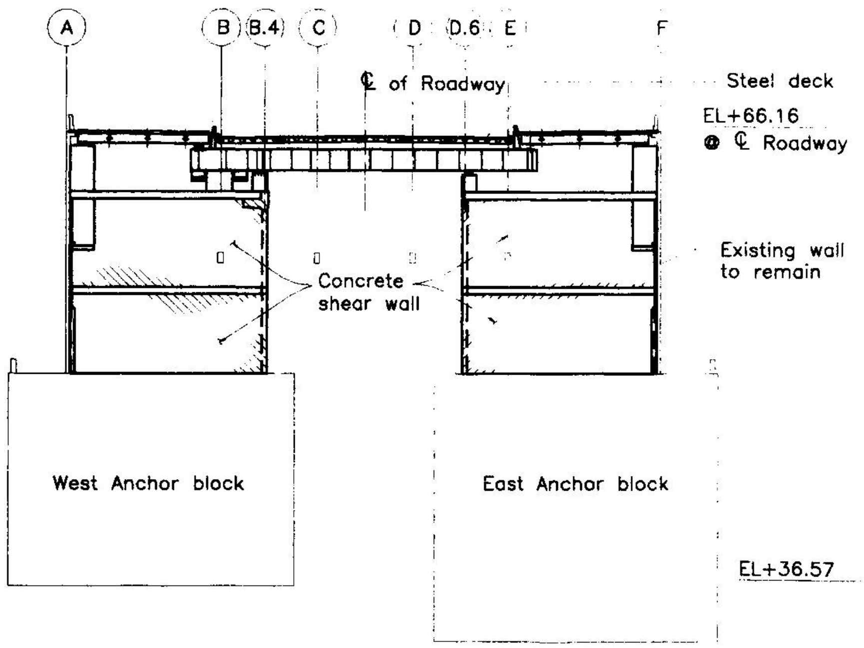
Faye Bernstein & Associates, working together with Ed K. McNinch & Associates, developed a redecking approach within the established design constraints. The new scheme provides a new vertical support system and a new deck at no additional cost than retrofitting the existing structure alone. Cost reduction was accomplished by elimination of shoring and costly retrofit items such as restrainers needed to retrofit the existing concrete roadway. In addition, the weight reduction in the deck created a cost savings in the supporting structure. For each kilogram of weight the structure had to resist about two kilograms of lateral load. With the new roadway support structure and deck installed, the historic appearance of the structure remains unchanged.

The proposed deck replacement will be done at night. To temporarily retain the existing verticalsupport system, new bents adjacent to existing ones will first be installed. The new bents allow for easy removal of existing deck sections while providing a new modern support structure with simple seismic details. Each night a portion of existing roadway deck will be removed,

BENTS ON ANCHOR BLOCKS AT NORTH SECTION



EXISTING BENT NO. 8



NEW BENT NO. 8.2

FIGURE 3

unloading the existing bents, and will be replaced with a new segment of steel orthotropic deck panel, supported on the new transverse bents.

6.0 STRUCTURAL SYSTEM

The retrofit design provides new transverse bents offset 1.5 meters from the existing bents. The new bents will ultimately provide both lateral and vertical support for the structure. New shear walls in the longitudinal direction augment the support provided by the existing exterior walls. The exterior walls are retrofitted to increase in-plane and out-of-plane capacity. The structural systems on the north and south portions of the housing differ slightly. The south system, founded on native rock, consists of hybrid frames in the transverse direction centered on the roadway, and shear walls in the longitudinal direction. The north section consists of shear walls in the transverse direction above each anchor block with deep roadway support girders spanning between the walls. Shear walls are used in the longitudinal direction to resist lateral loads.

The new walls terminate in wide horizontal beams about 3.5 meters below the deck. The beams span between perpendicular walls and will be utilized as catwalks. The reasons for the lowered walls include reduction in weight, reduction in lateral loads to be transferred by the new deck, ease of construction before redecking, and open access below the deck during and after construction.

Exterior walls in the longitudinal direction are retrofitted to increase their in-plane and out-of-plane capacity. Vertical steel trusses will be installed to brace the walls out of plane. Some shotcrete will be added to the bottom portion of walls to increase in-place shear capacity.

7.0 CONCLUSION

The seismic retrofit process has produced an upgrade which extends the lifespan, increases seismic safety and reduces maintenance, while maintaining the historic appearance of the Golden Gate Bridge. A cooperative effort between the engineering staff of the Golden Gate Bridge District and structural consultants, has resulted in a design which best serves the long term operational needs of the District. A strength of the design process was maintaining flexibility to incorporate new information as it developed. Two milestone pieces of information which significantly altered the design were the identification of the potential for anchor block rocking and the cost control which identified deck replacement as viable. The flexibility in the design process incorporated the new deck into the seismic retrofit work; and as a result, reduced the cost of the seismic retrofit.