Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design and procurement of dockside container handling cranes and other complex structures. Our experience includes structural design for wharves and float structures, heavy lift structures, buildings, container yard structures, and container handling equipment.

Erik Soderberg is Liftech's president and a structural engineer with experience in the design, review, and modification of a variety of structural systems including hundreds of container cranes, over a dozen bulk loader structures, and over two dozen wharves and piers. Other structures include crane lift and transfer systems and concrete and steel floats.

Location

Key locations include:

Project site, indicated with the large white star

Oakland, across the water to the right, the upper land mass

Golden Gate Bridge, north of San Francisco above the "S" in San Francisco

Bay Bridge (SF seawall location), the arc shape from the star to Treasure Island and beyond

Port of Oakland, across the water to the right, upper land mass, bottom blue dot

Liftech office, across the water to the right, upper land mass, top blue dot

Site History

Source: Shaw Kawasaki Architects

Like many locations along the waterfront, the project site used to have a long pier that extended far into the water (indicated by the white star).

Topics

Project background

Earthquake design—pile requirements

Estimated seawall movement

Pile evaluation

Pile pinning

Seawall arching

Findings and design considerations

The photograph on the right is the current pier with storage shed. Many of the piles are damaged, and the fire boat fleet exceeds its berthing capacity.

This presentation will include an overview of the project, present pile design requirements, the calculated seawall movement, our evaluation of the piles, and discuss several issues we encountered including pile pinning of the seawall, seawall arching, and some findings and conclusions.

Rendering 1

Source: Shaw Kawasaki Architects

This graphic shows looking from San Francisco toward Oakland. The people are standing on the pier in San Francisco with the Bay Bridge spanning from San Francisco to Oakland on the right. The seawall bulkhead runs along the waterfront under the landside fencing shown.

Liftech is the lead marine design consultant for the new design-build floating fire station project, San Francisco Fire Boat Station 35.

Note the existing fire station on the left, new fire station on the float on the water to the right, ramp with an emergency vehicle, **seawall,** and **location of pier piles.**

This is the **first floating fire station** in the United States.

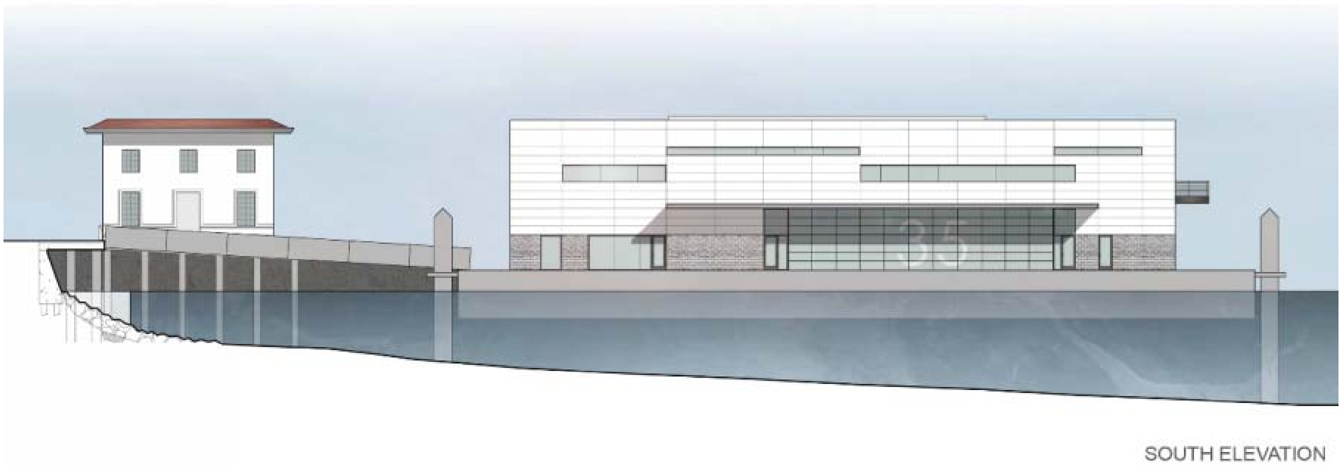
Rendering 2

Source: Shaw Kawasaki Architects

This graphic shows looking toward San Francisco with the Bay Bridge in the background.

Firefighters will be quartered on the floating station, which contains a family room, kitchen, and deck. Since they will be spending significant amounts of time on the float, including eating and sleeping, the float is designed to limit the amount of motion. For example, the pile collars have dampers that will significantly mitigate the float's impact with the piling.

Cross Section



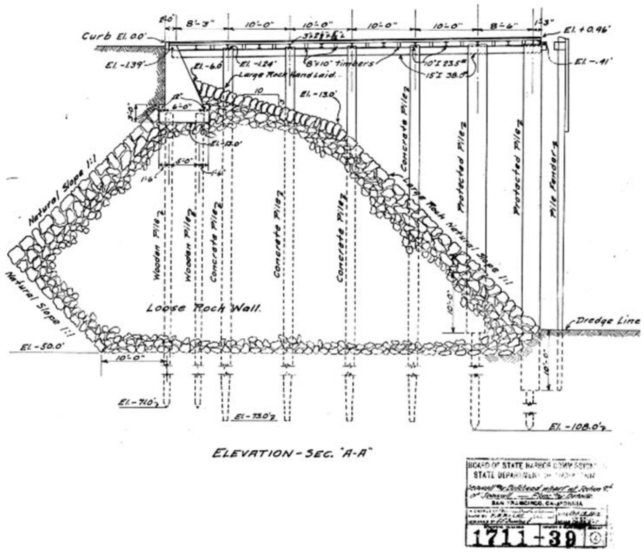
Source: Shaw Kawasaki Architects

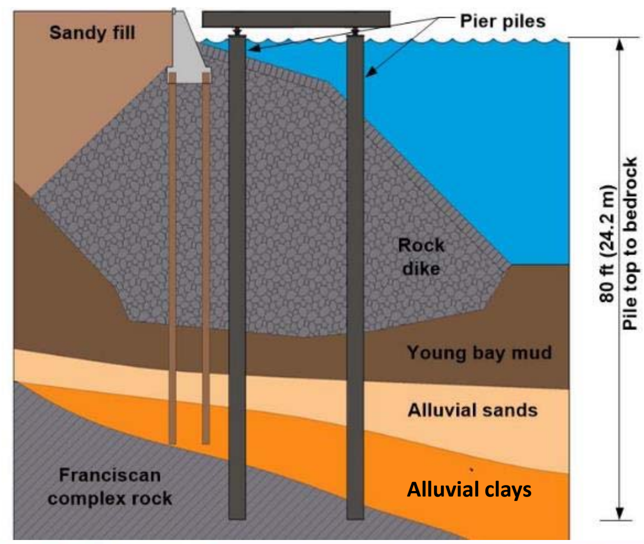
This presentation will focus on four new 36 in (1 m) diameter, 1 in (25 mm) thick wall piles that are used to support a prefabricated pier superstructure. These piles will extend through the existing seawall.

The larger, 60 in (1.5 m) diameter piles used to moor the float are far enough away from the seawall that they are unaffected by seawall movement.

The design water range is 19 ft (5.8 m) including sea level rise and design tsunami. The floating station design accommodates the expected varying water levels with limited motions and favorable access to the fireboats and jet skis.

Original Seawall Foundation & Soil Profile



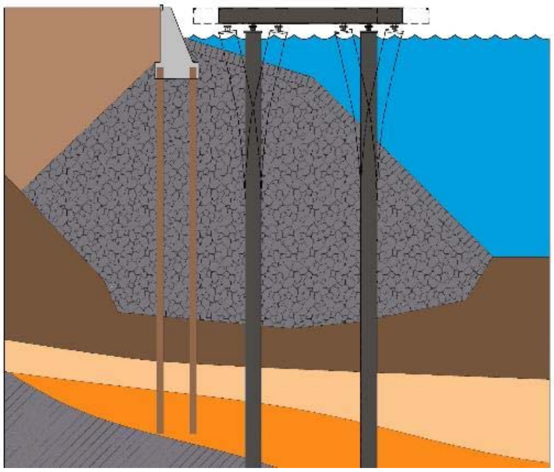


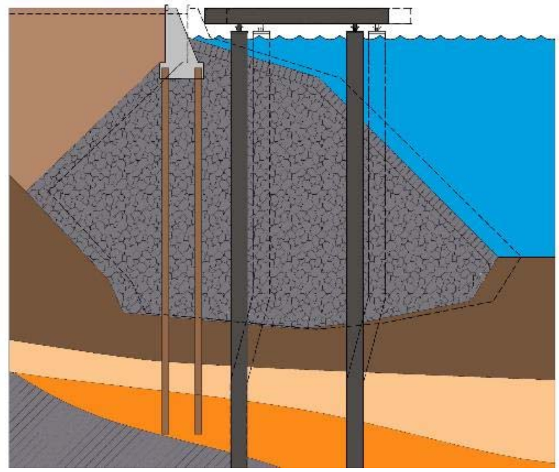
Source: Original design drawings

The original and existing seawall (**to be demolished**) consisted of a large rock embankment around a wooden pile-supported concrete bulkhead that is 13 ft (4 m) deep and 6 ft (2 m) wide. Unconsolidated fill material exists landside of the wall.

The thin layer of Young Bay Mud is relatively weak and is a key reason the seawall moves into the bay during large earthquakes.

Pile Earthquake Design Considerations

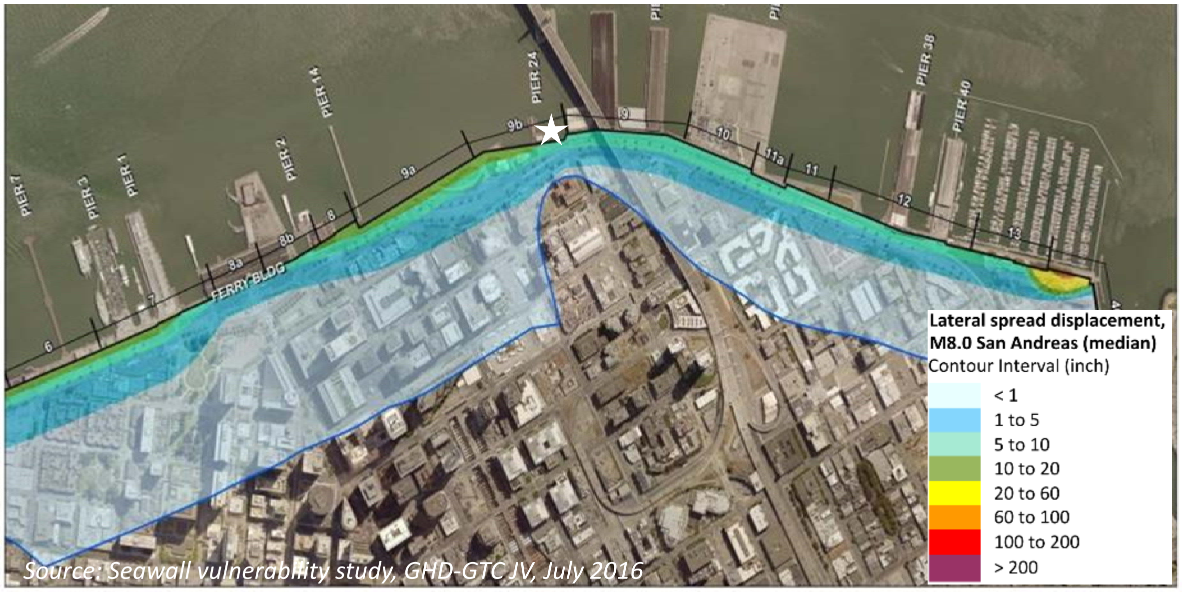

Inertial loading


Kinematic (ground movement) loading

The pier piles are designed for two different loadings: (1) the vibration of the pier during ground shaking, and (2) the piles moving with the embankment when it moves toward the bay.

The design movements for the DE were about 3 in (75 mm) for the inertial loading and about 12 in (300 mm) for the kinematic loading.

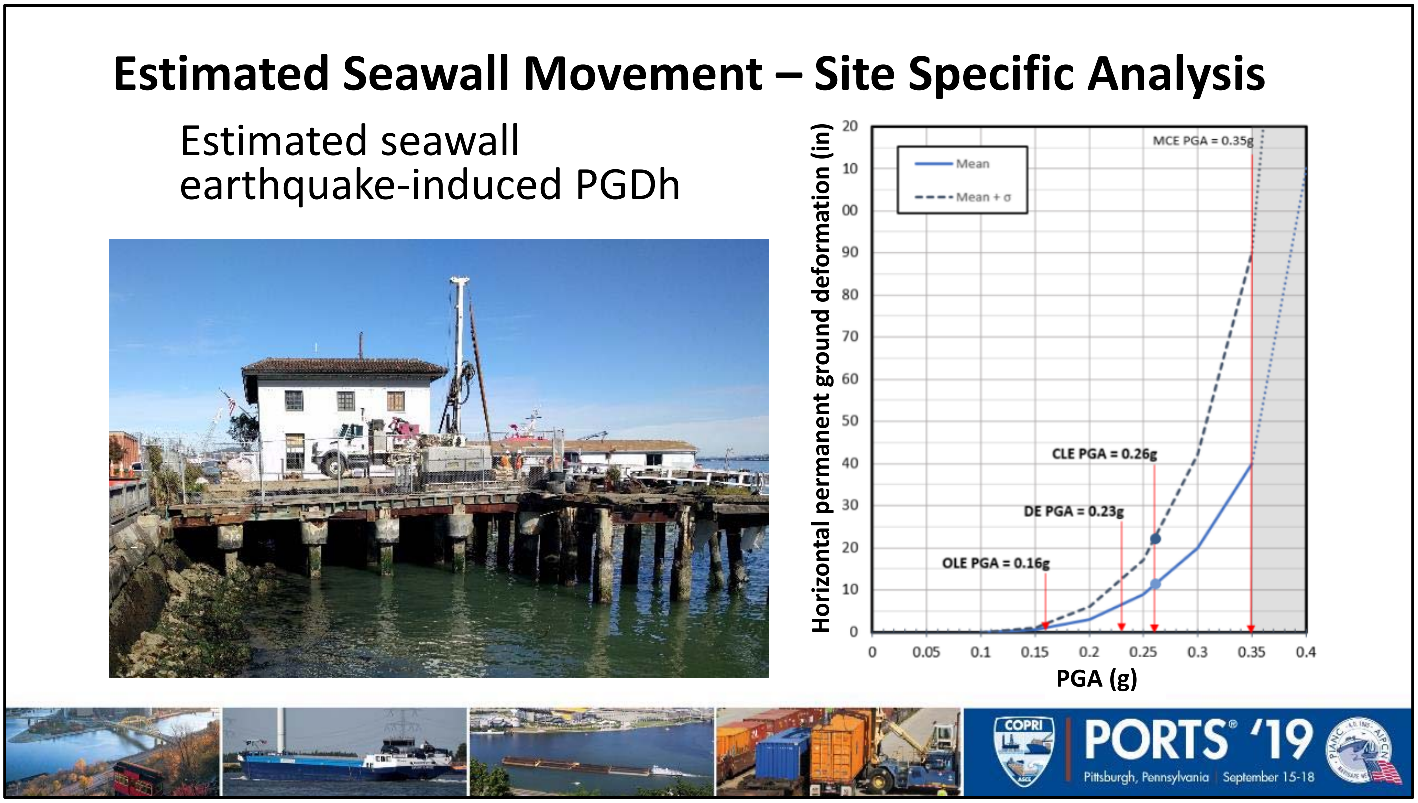
Estimated Seawall Movement: Port of SF Study



At the beginning of the project, the amount of seawall movement was estimated based on a 2016 study that estimated 5 in to 10 in (125 mm to 250 mm) of seawall movement at the project site from an M8.0 earthquake on the San Andreas fault.

The blue line is "zone of influence."

Notice that the project site has less expected movement than other locations, partially due to the favorable geology and less fill.



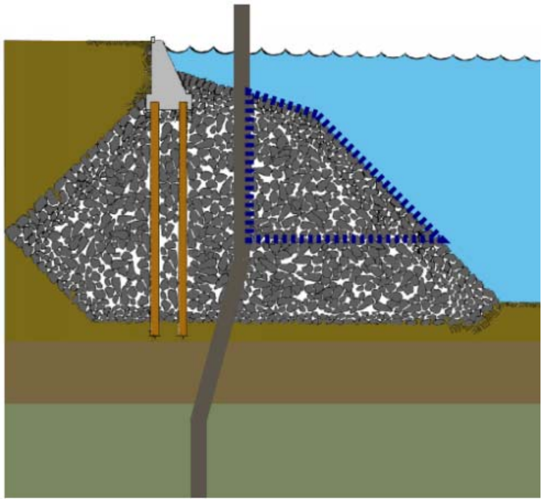
For the project, borings were made to obtain Bay mud samples that were then tested for dynamic shear strength. Three borings were made through the rock dike to obtain two samples of Bay mud.

After significant geotechnical analysis, the lateral seawall movements shown in the right graph were provided. The solid line is the average calculated displacement from multiple design earthquakes. The upper dashed line is one standard deviation from the mean, showing the variability in response from the considered earthquakes.

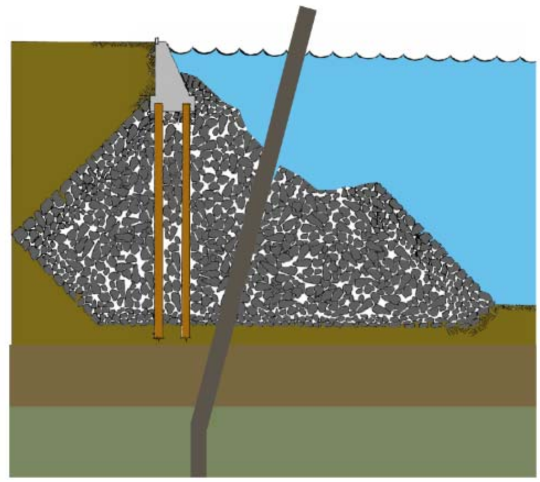
The seawall movement estimates presented do not account for the effect of pile pinning – the resistance of the existing wooden piles and new steel piles in resisting the seawall movement.

Pile pinning affects were not included in the analysis as it was determined the new piling would meet the design criteria for the calculated seawall movements not considering pinning effects. This resulted in less engineering effort.

Pile Evaluation – Anchorage in Embankment



(a) Lower and upper hinges form



(b) Only lower hinge forms

The rock embankment was determined to be strong enough to anchor the top of the pile and to bend the upper portion of the pile.

Two plastic hinges are expected to form in large seawall movements.

This anchoring and reverse curvature significantly increased the pile pinning resistance even though it was not counted on in the geotechnical analysis.

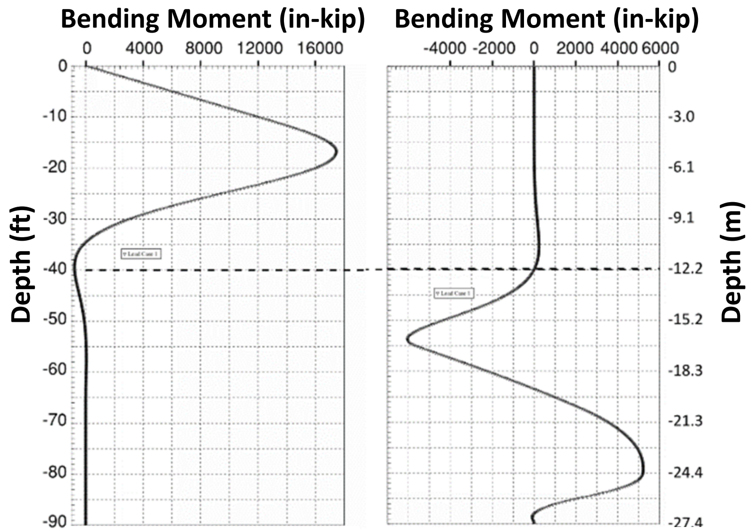
Normalized Soil Spring Stiffness Along Pile

Distance below Pile Top ft (m)		Layer	Normalized Soil Spring Stiffness
-15	(-4.6)	Rock Fill Layer	11
-20	(-6.1)		20
-30	(-9.1)		38
-40	(-12.2)		56
-50	(-15.2)		74
-55	(-16.8)		83
-60	(-18.3)	Young Bay Mud	1
-65	(-19.8)		1
-70	(-21.3)	Alluvium	5
-75	(-22.9)		5
-80	(-24.4)	Bedrock	1900

As shown, the relative soil spring stiffness varied significantly along the pile length.

Pile Inertial and Kinematic Interaction

Pile bending moments under parameter loadings

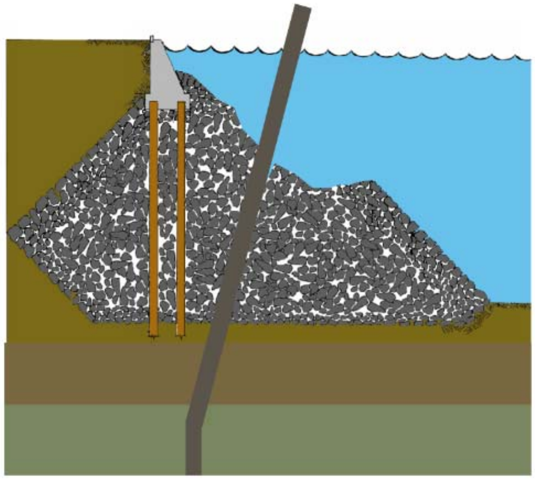


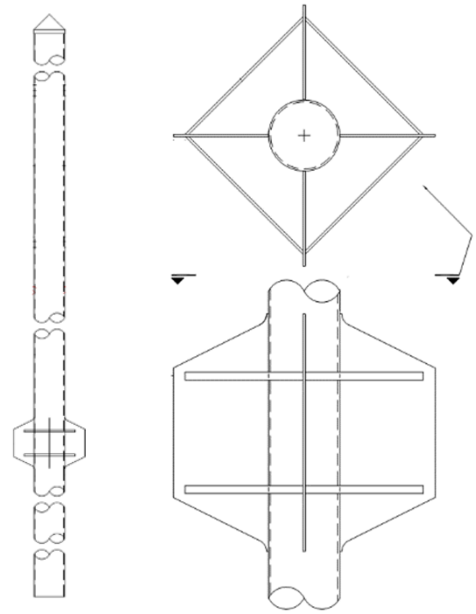
Pile moment diagram under **Inertia Loading**

Pile moment diagram under **Kinematic Loading**

Analyses indicate that the strains in the piling from inertial loading and kinematic loading from the seawall moving will occur at drastically different locations along the pile.

Pile Pinning

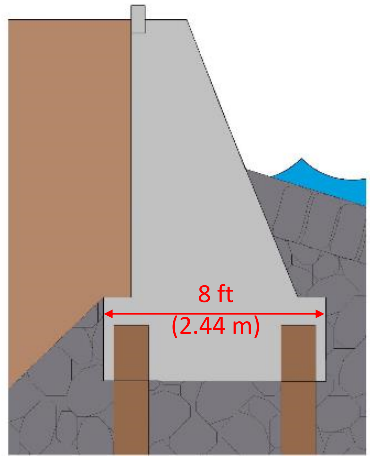




Early in the project, pile fins were considered to increase the soil reactions for laterally anchoring the piling; however, they were determined to not be needed.

Pile fins had been used previously for dolphin piles—Reference Ports 2013 Presentation.

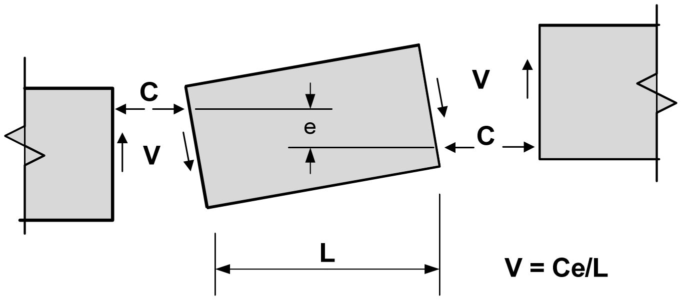
Seawall Bulkhead Arching Across Site



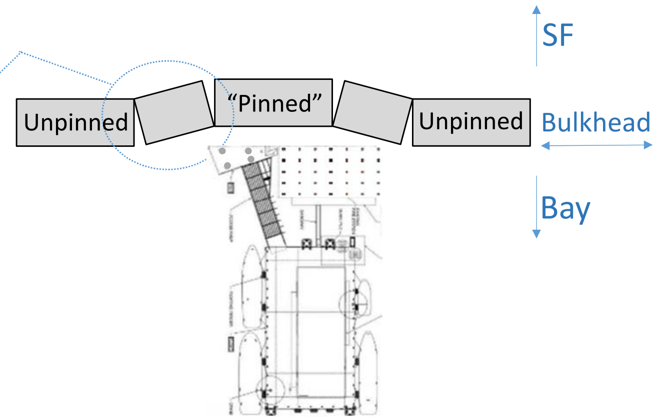
Source: Original Design Drawings

In our initial pile pinning evaluation, we studied how the large bulkhead may span across our project site. Even though we may pin the seawall at our site, the seawall movement adjacent to our site could impart large loads through the bulkhead onto the pinned embankment at our site.

Seawall Bulkhead Arching



Arching free body diagram



Plan view
Not to scale

We used the free body diagram shown to estimate the bulkhead lateral capacity.

The bulkhead is shown in segments. The segment at the site shown as “pinned” restrains movement of the embankment and bulkhead locally.

We estimated a shear capacity of over 500 kip (225 tonne) at L=50 ft (15 m).

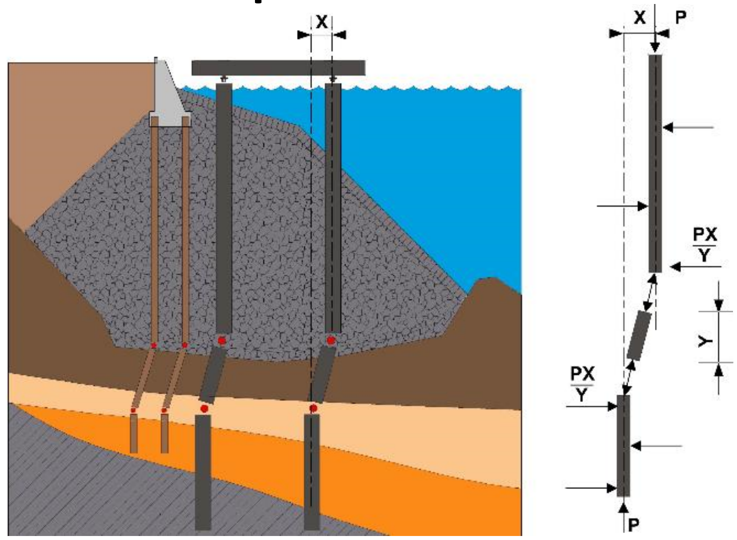
Comments on ASCE 61-14 – Strain Limits

- Constant and not related to section compactness
- ASCE 61 committee addressing this issue in next version
- Piles in this project:
  - Meet current strain limits
  - Almost meet strain limits being discussed for next ASCE 61 version

ASCE 61-14 strain limits are not related to the compactness of the pile section (diameter / wall thickness).

This is being addressed.

Pile Performance Acceptable Without ASCE 61 Limits



Pile hinging due to kinematic loading

Much larger strains than allowed by ASCE 61 are acceptable for this condition.

If hinges that carry no moment form in the piling, the piles can still carry the design vertical loads as the lateral soil reactions to stabilize the piles are small, and the axial stress is small.

Findings

Soil layers varied significantly in stiffness and strength.

Maximum bending from inertial and kinematic loadings occurred at different pile locations.

Design seawall movement did not result in excessive pile strains.

Pile may provide significant shear resistance if it forms two hinges, or where there is a thin bay mud layer below the seawall, or both. Large piles can provide significant pinning strength.

Modest lateral soil reactions can stabilize the "pinned" pile segment and maintain pile axial capacity if the pile develops hinges carrying no moment.

The effect of pile pinning was initially considered for the embankment movements, but it was determined that the effect did not need to be considered to comply with the project criteria, i.e., the free field embankment design movements were less than the allowed pile deformations.

If plastic hinges form and large soil movements are expected, use a compact pile section to ensure capacity does not deteriorate after limited seawall movements. Large piles will provide significant pinning strength. If movements can be limited, non-compact piles may be acceptable and worthwhile.

Design Considerations

Seawall bulkhead arching:
- Can transmit significant shear
- Consider when estimating bulkhead lateral capacity
- Consider isolating seawall bulkhead from rock dike

Evaluate rock dike capacity to ensure pile will not rotate through dike.

Consider more compact pile section if large seawall movements and hinges form.

Consider less compact pile section if limited seawall movements.

Compactness = pipe diameter / wall thickness


Thank You
Seawall Movement and Piling Design at the San Francisco Waterfront
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