Part 6

TIED BACK OR RESTRAINED WALL SYSTEMS

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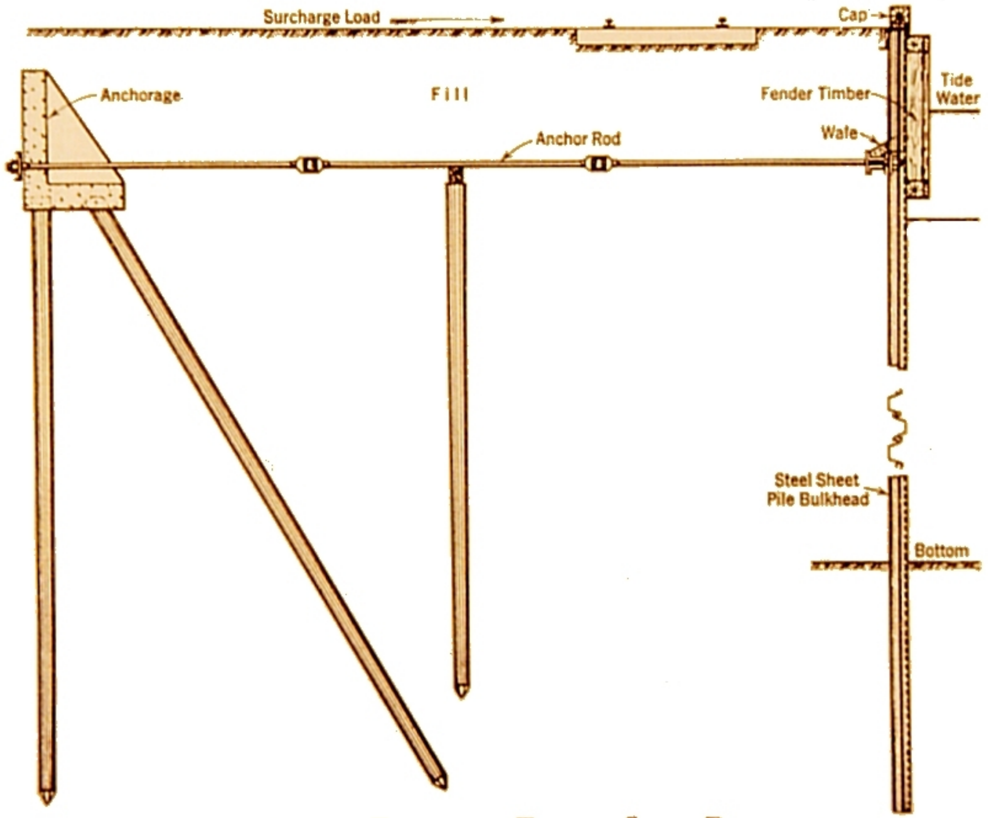
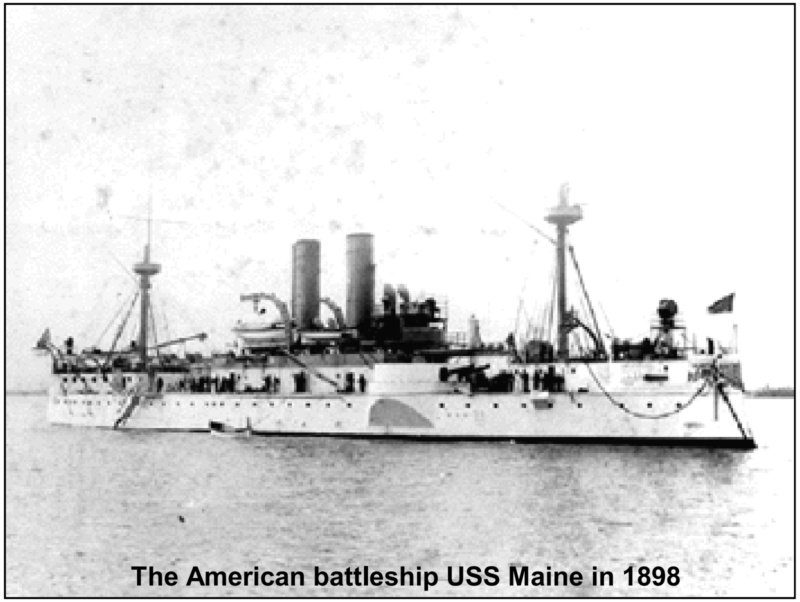


Fig. 1. Section Through a Typical Steel Bulkhead

- Flexible steel bulkhead walls became commonplace during the 1920s and 30s for expanding harbor and dock facilities on soft ground
- This views shows the various components

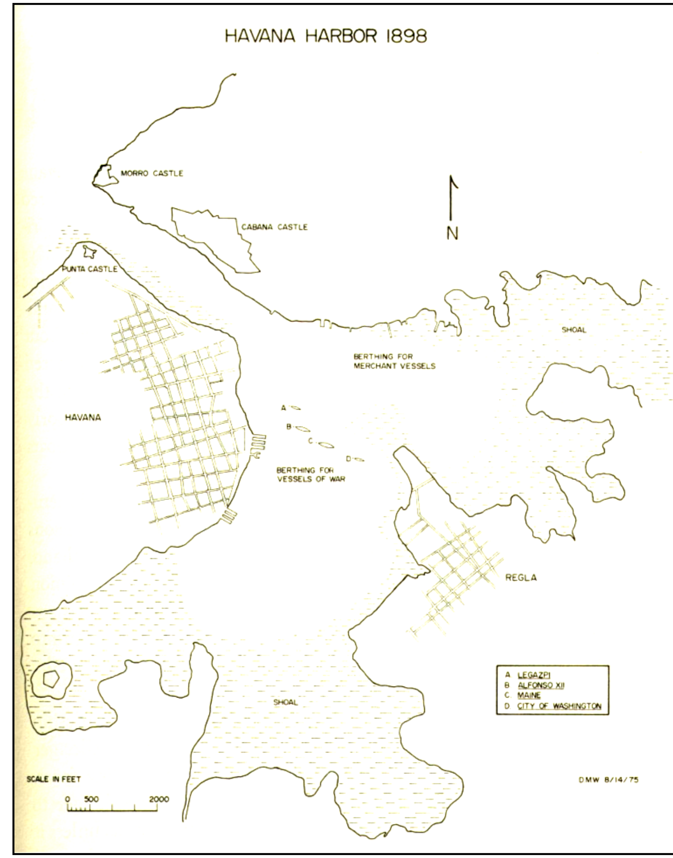
Raising a sunken battleship in Havana Harbor



The American battleship USS Maine in 1898

The hulk of the USS Maine in Havana Harbor in 1911

Army Engineer Colonel William M. Black was the first to employ a series of interlocking circular steel sheetpiles to construct a cofferdam allowing the examination and removal of the battleship Maine in Havana Harbor, Cuba in 1911-12.



The USS *Maine* was sent to Havana in January 1898 to protect American interests during the long-standing revolt of the Cubans against the Spanish government. Three weeks after her arrival, on 15 February 1898, the *Maine* sank when her forward gunpowder magazines exploded killing nearly three-quarters of the crew. Her sinking provoked the Spanish-American War that erupted in April 1898. The *Maine*'s wreck was raised in 1912 to clear the harbor and to facilitate an investigation of why she exploded. The true reason (an accidental internal explosion) wasn't unraveled until 1976.

Circular cofferdam used to exhume the sunken battleship Maine

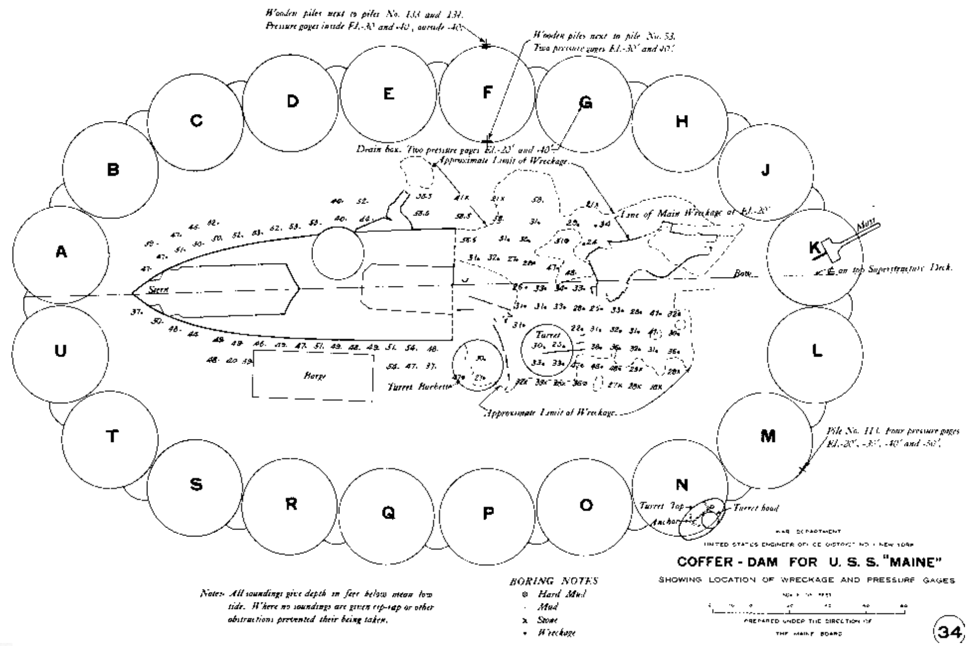


PLATE 21.—FILLING CYLINDERS, HYDRAULIC DREDGE "NORMAN H. DAVIS" AND DIPPER DREDGE "SAGUA."

Upper left: The initial dewatering attempt (shown here) was unsuccessful because the caissons were filled with dredged silt and clay from the perimeter of the sunken hulk, which would not drain.

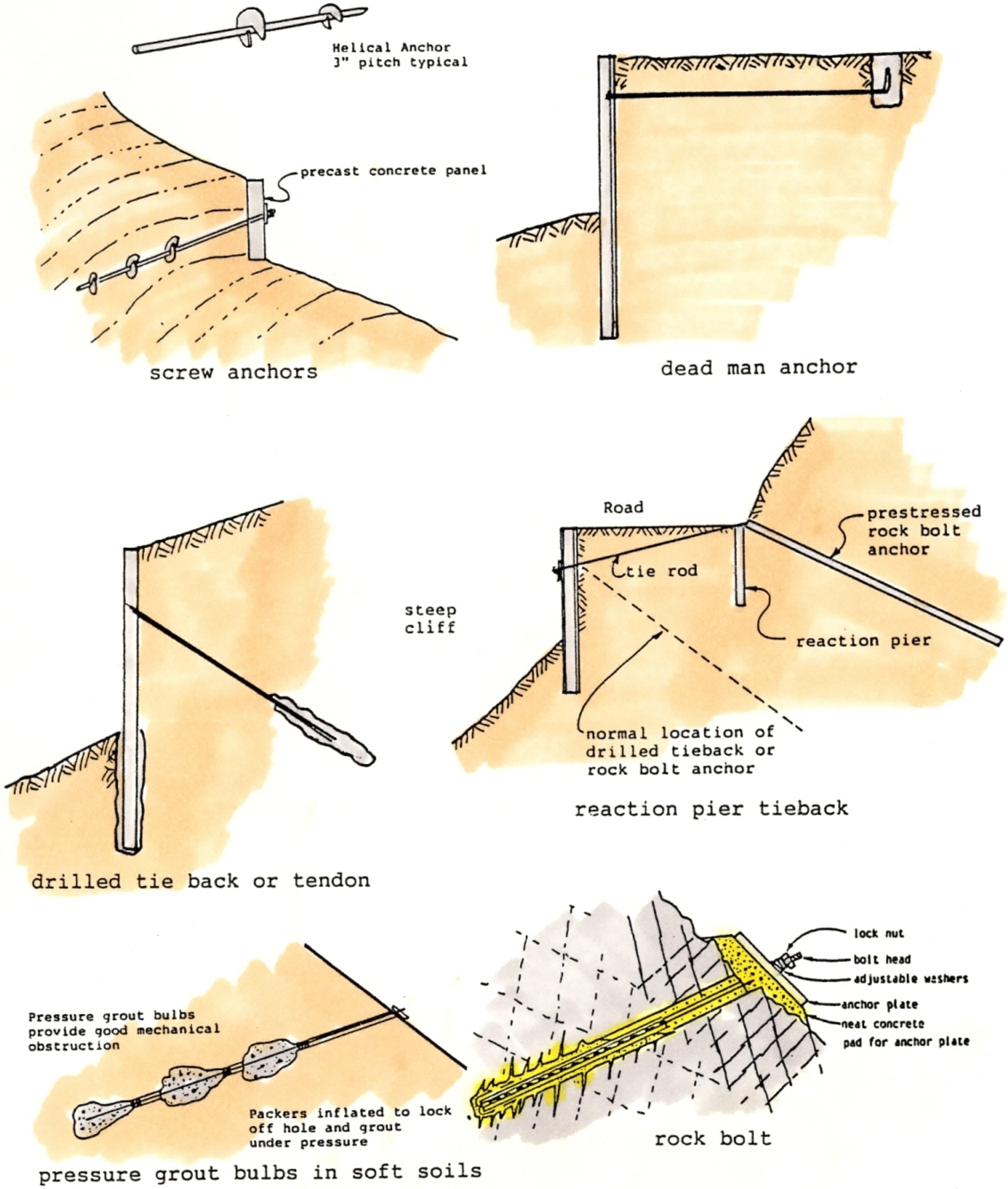
Lower left: The stability problems were finally solved by using filling the cells with free-draining sand dredged from some distance away, as seen in the background.

Cellular Cofferdams

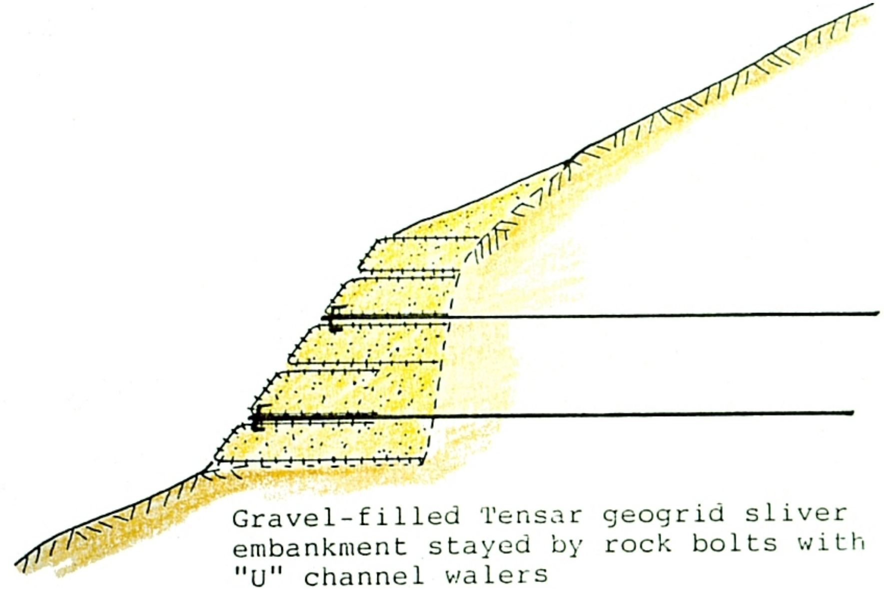
Navy Seabee construction battalions built hundreds of breakwaters (above right) and harbor facilities during the Second World War using cellular cofferdams. The cells were filled hydraulically (upper left) using dredges feeding crushed coral (lower left), which was free darining. These structures were usually protected with zinc strips for cathodic protection.

- **Upper: Interconnected cellular sheetpile cofferdams are often employed to construct facilities "*in-the-dry,*" below a permanent water surface, such as this lock and dam structure. Note free draining fill being placed in the cells using clamshell draglines**
- **Lower: Circular sheetpile cofferdams can also stand alone in a line along a river or waterfront, as shown here. They are often employed for *below-water excavations*.**

- **Self-sustaining sheetpile cofferdams** can be used to dewater entire construction sites, as shown here. This is for a Corps of Engineers lock and dam structure.



- **Various types of restrained wall systems, using tiebacks, soilnails, screw anchors. deadmen anchors, rockbolts, grout bulbs, and/or combinations thereof.**



Tensile reinforcement elements have been combined with flexible retaining walls for a long time. The example at left shows a sacrete wall structure that employed rebars with face plates to construct a bulkhead wall for a quarry loading structure

The example at right shows rebar ties with channel walers (sometimes referred to as “belt beams”) being used in combination with a mechanically stabilized embankment of narrow proportions

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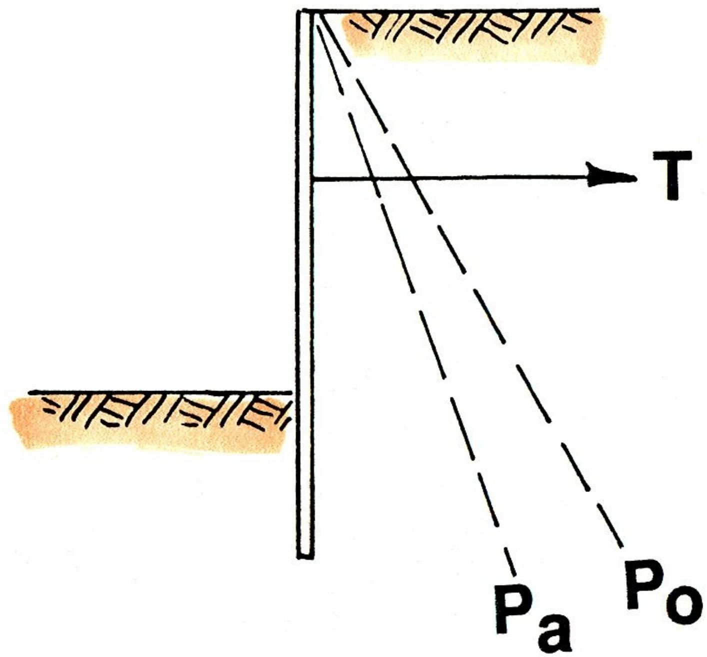
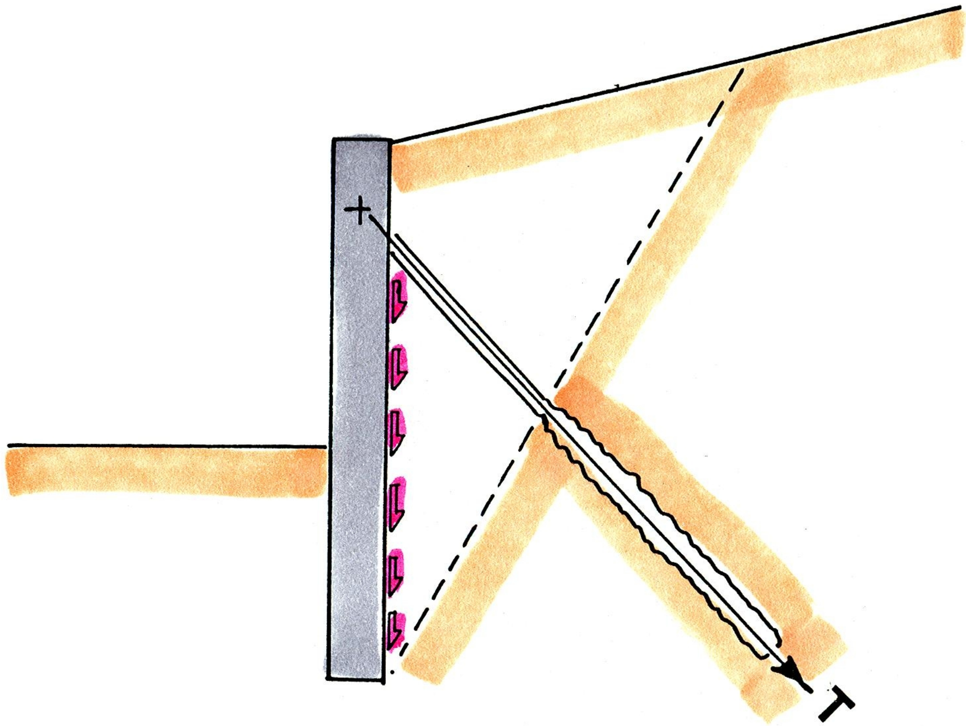


RESTRAINED WALL

- **The employment of tensile anchors restricts the outward relaxation movement of the cantilever wall element, causing an At-rest earth pressure condition, which are typically 33% greater than active earth pressures**



Inducing a negative down force on pier by post-tensioning tieback

- **If inclined tiebacks are used, an appropriate downdrag factor on the back side of the cantilever element must be accounted for, as sketched here**

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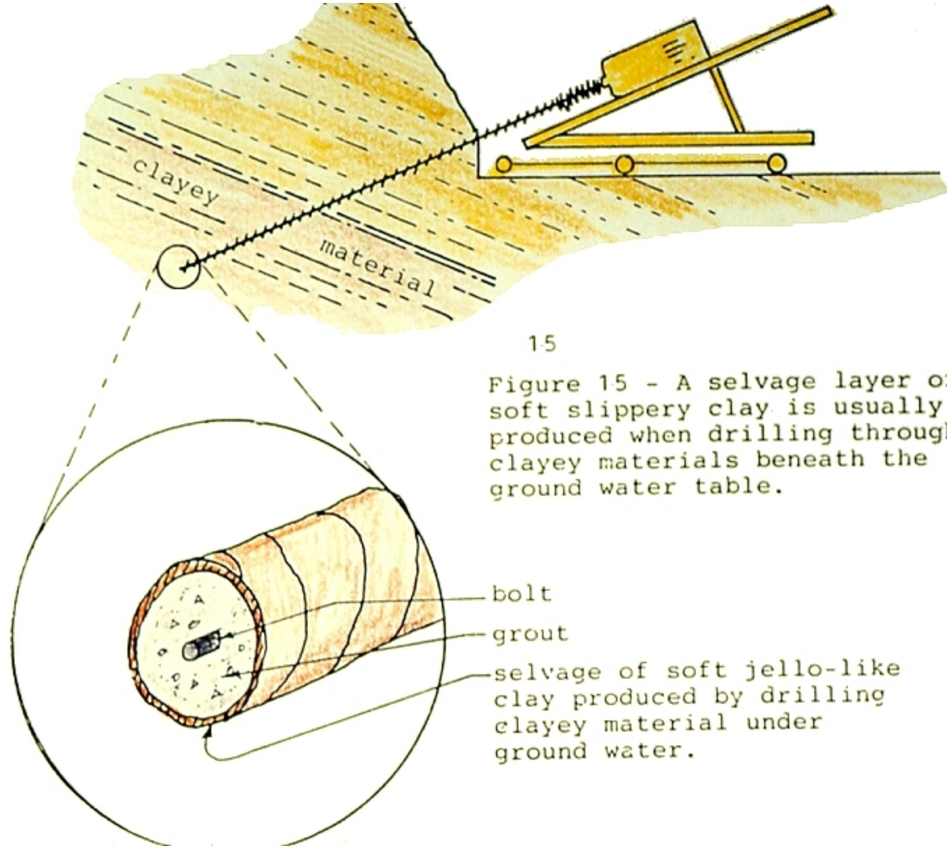
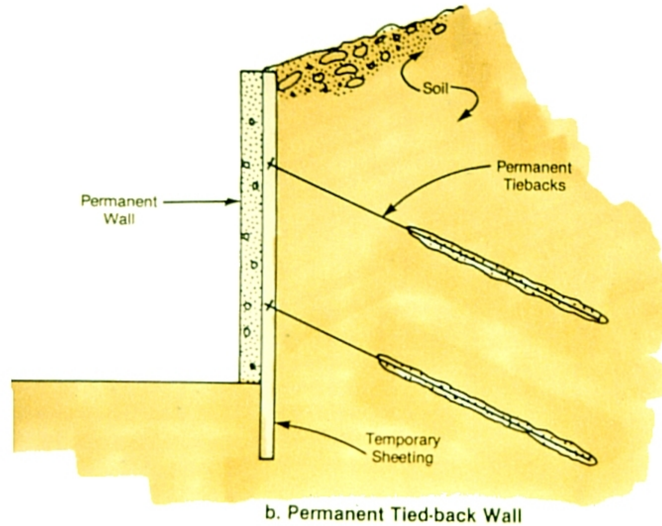
- **Tiebacks are usually excavated using continuous flight augers, as shown here. Care must be exercised to drill the holes in exact locations, alignments and inclinations**



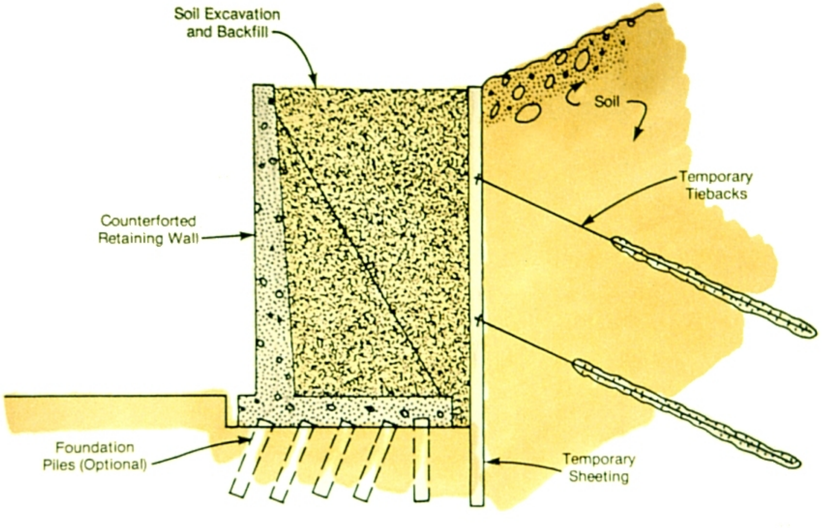
Tiebacks excavated in clayey materials beneath the water table may exhibit unexpectedly low skin friction, due to the build-up of drill cuttings around the annulus of the auger hole. Such anchors may pull out well below their design capacity. This is a liability when excavating tiebacks in landslides or shales. Tiebacks generally have performance specifications which require pull testing.

- Another critical component of tiebacks is the detail of the anchor head attachment between the tieback and the cantilever elements.
- These must be strong enough to resist twisting and eccentric loading of the cantilever



Comparison of a Conventional Retaining Wall with a Permanently Tied-back Wall

Tied-back wall systems are often employed behind finish walls, as shown here. Finish or interior walls cannot be allowed to deflect noticeably, hence the need for tiebacks. The tiebacks also reduce the earth pressures on the permanent wall, constructed inboard of the temporary wall.



a. Conventional Retaining Wall

The example at right shows three rows of incined tiebacks. Note the employment of inverted channels being used as waler stiffeners for the anchors at right. This allows spreading of load between adjacent tieback anchors and lessens reliability on individual anchors.

These walls are often constructed as temporary support for permanent walls that will later be constructed inboard of them, as sketched above left.

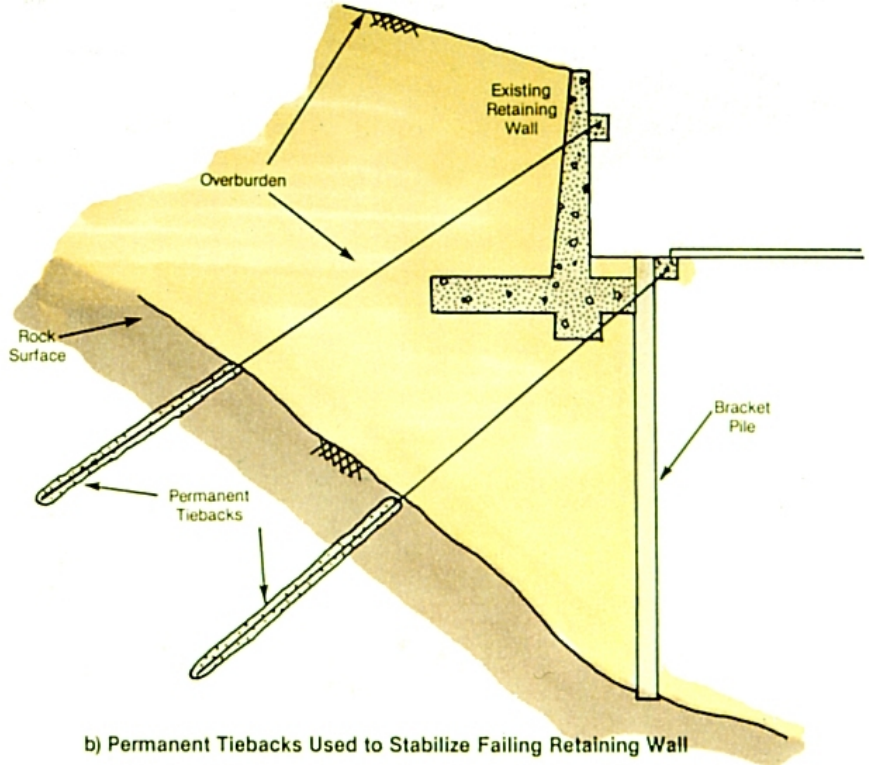


Figure 4. Repair or Reconstruction of Existing Structures

- **Tieback anchors can also be used to repair existing structures, as sketched here. Care must be exercised to provide for corrosion protection, especially when using prestressed tendons.**

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- **Double row of tiebacks with a reinforced concrete bulkhead wall in Seattle, WA. This wall is battered to reduce the lateral earth pressures. Tieback loads are spread along vertical stiffener beams**

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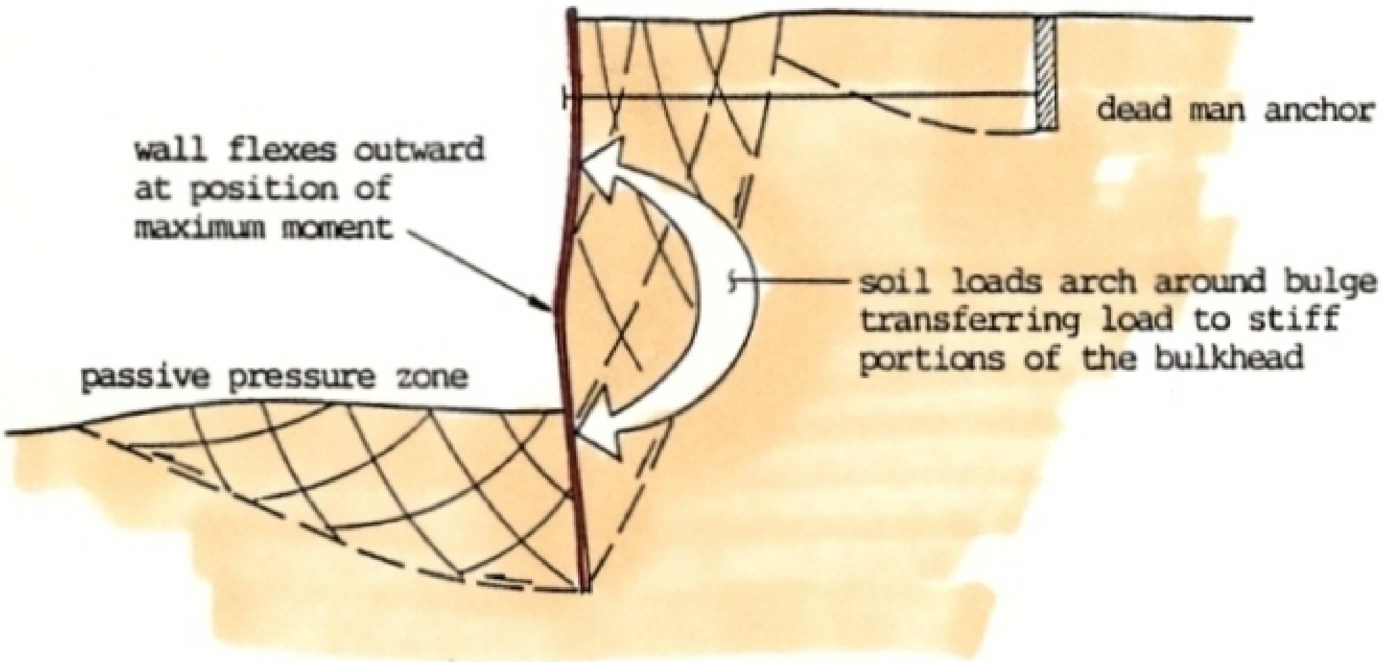


- **Flexible bulkhead walls operate on the principle of arching, where the lateral soil loads are transferred in large part to the deadman anchor and passive reaction zone, as sketched above. This allows much lighter cantilever elements to be used for the wall**

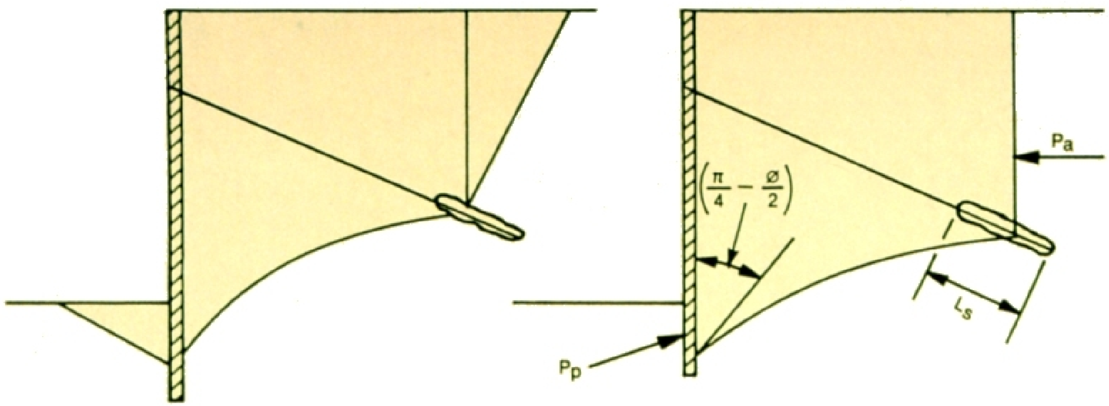


Figure 12. Simplification of the Wall-Anchor System for Stability Analysis

- **Tieback anchor reaction zone behind a bulkhead wall (above left). For purposes of design this zone is simplified, as shown at right.**

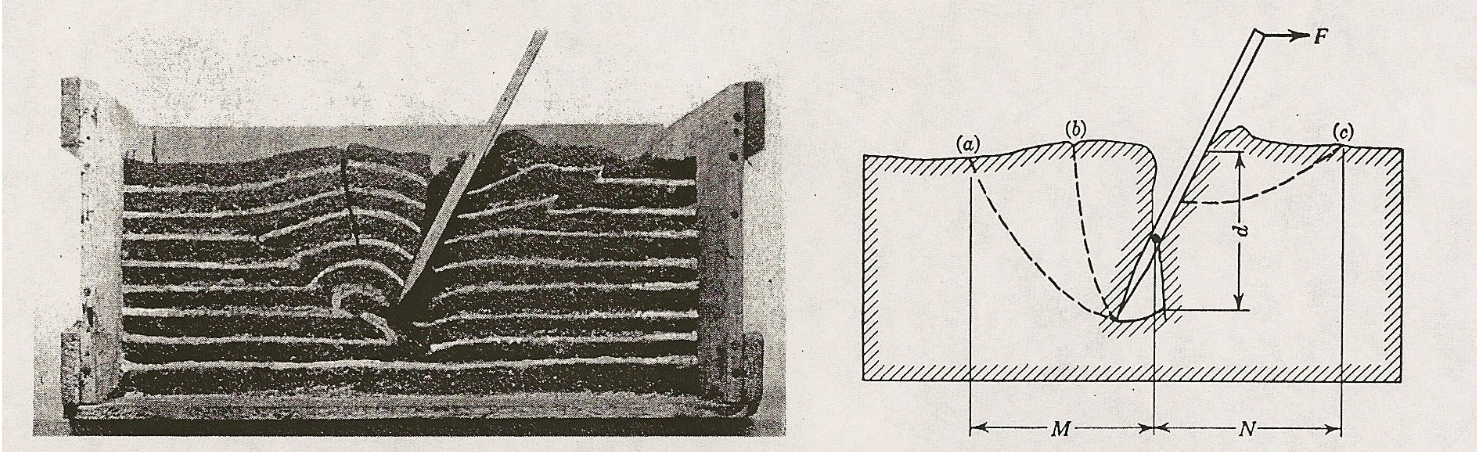
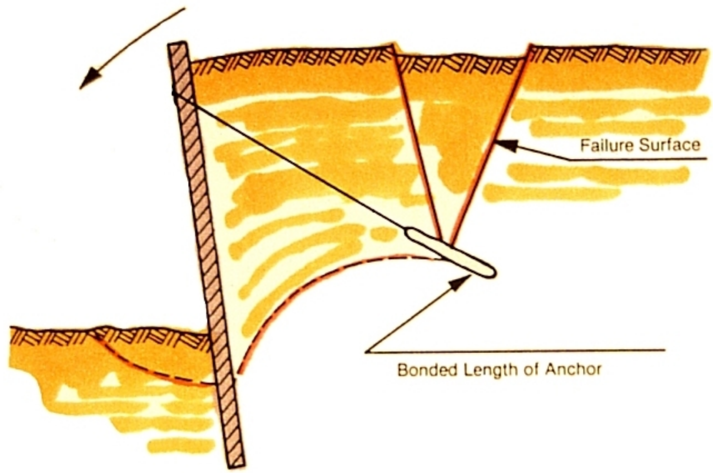


FIG. 2. SHEARING ACTION OF A SHEET PILE; RESULT TYPICAL OF A HUNDRED EXPERIMENTS



- **Upper: Failure of a stiff bulkhead wall, from Krynine & Abbett (1933) Lower: failure of tieback anchor, illustrating the reaction zones and failure surfaces. Note the graben that develops behind tilted wall.**

- **Collapse of a sheetpile bulkhead wall due to failure of turnbuckle hooks on short deadman anchors, which were ties to a concrete road (from Tschebotarioff, 1951)**

Steel sheetpile bulkhead walls must be provided with cathodic protection if placed in proximity to brackish or saline water.

The upper left figure shows a bulkhead wall on Midway Atoll, with conventional deadman anchors. Note waler at waterline.

The lower view shows anodes installed on back side of PZP-38 sheetpiles at Midway Atoll inner harbor/wharf facility.

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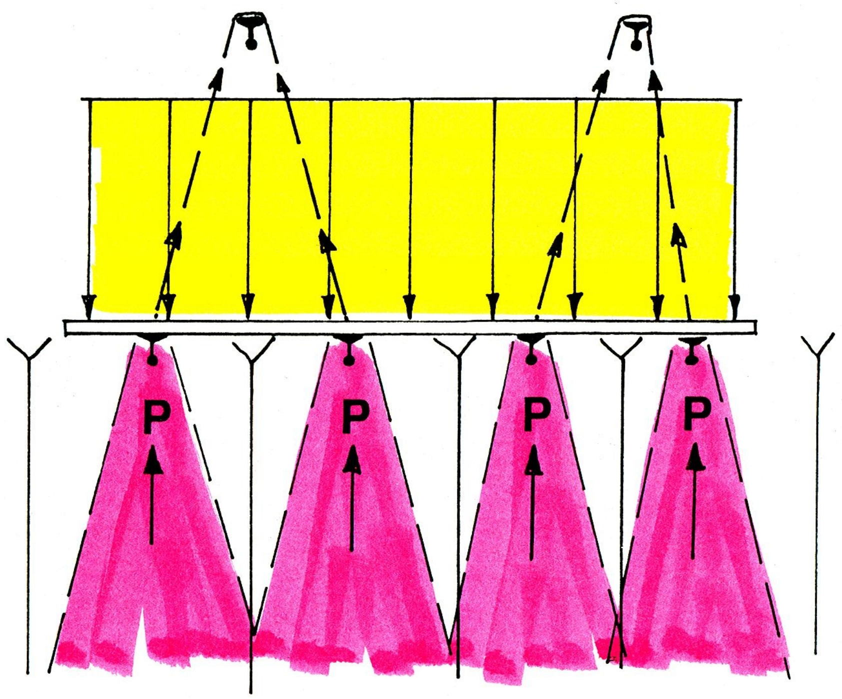
- Toe kick-out failure of cantilever walls most often occurs when the cantilever elements are thin, as shown here.
- Common examples of thin elements are railroad rails, telephone poles (shown here) and steel I-beams
- This wall was tied back

TIED-BACK RAIL RETAINING WALLS ARE DANGEROUS!



- **The width of the effective passive reaction wedge is only twice the nominal width of the embedded element in the ground. For rail retailing walls, this width may be less than 8 inches!**

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- Titled tied-back cantilever retaining wall being replaced. It is very difficult to design a cantilever wall on a slope because of the paucity of passive reaction area, not to mention slope creep.