Guide to Siting of Seawalls

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by

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Introduction

Overview:

This White Paper is to offer guidance to minimize the threat to turtle nesting habitat via the siting of seawalls as may be permitted by the Florida Department of Environmental Protection (FDEP).

Florida's beaches are a recreational attraction to residents and tourists, but a healthy beach and dune system is also necessary for marine turtle reproduction. Typically, sea turtles nest along Florida's beaches from March through October on Florida's east coast and from April through October on Florida's west coast. However, coastal construction threatens sea turtle nesting habitat. Coastal armoring – including seawalls, revetments and other hard structures - are a particular threat to this turtle nesting habitat.

A 2011 study (Rizkalla & Savage, 2011) of sea turtle nesting along a 1.7-km of beach in Indian River County, Florida indicates "that seawalls impact loggerhead sea turtle nesting by reducing nesting success and increasing the likelihood of nests being washed away during storm events." Similarly, another study (DBS, 2011) found that for the 2011 turtle nesting season on Singer Island, turtle nesting densities, nesting success, and hatch and emergence success were significantly lower in a study zone dominated by seawalls.

On Singer Island in Palm Beach County, numerous seawalls have been constructed and more seawalls are currently proposed. In response to these Singer Island seawalls, Larry Williams, a Field Supervisor for the U.S. Fish and Wildlife Service has identified (USF&WS, 2013) that: "Threats to nesting sea turtles posed by armoring include the following:

1. Reduction of nesting habitat;
2. Displacement of sea turtles to sub-optimal nesting habitat (*e.g.*, a lower beach elevation where eggs would be inundated);
3. Increase in the physiological cost of cost of nesting due to habitat alterations;
4. Decrease in nesting activity (*e.g.*, increase in false crawls);
5. Physical changes to the coastline that would result in decreased nesting habitat quality; and
6. Entrapment of nesting turtles."

Governing Statutes & Rules:

Section 161.085 of Florida statutes governs permitting of "Rigid coastal armoring structures" by FDEP; the statute cites:

- The state recognizes the need to protect private structures and public infrastructure from damage or destruction caused by coastal erosion.
- Permits for present installations may be issued if it is determined that private structures or public infrastructure is vulnerable to damage from frequent coastal storms.
- Permits for present installations of coastal armoring may be issued where such installation is between and adjoins at both ends rigid coastal armoring structures, follows a continuous and uniform armoring structure construction line with existing coastal armoring structures, and is no more than 250 feet in length.

FDEP rules for armoring are prescribed by Section 62B-33.051 of Florida administrative Code; these rules cite:

- (1) (a) Construction of armoring shall be authorized under the following conditions:
    1. The proposed armoring is for the protection of an eligible structure; and
    2. The structure to be protected is vulnerable.
- (2) Siting and Design. Armoring shall be sited and designed to minimize adverse impacts to the beach and dune system, marine turtles, native salt-tolerant vegetation, and existing upland and adjacent structures and to minimize interference with public beach access, in accordance with the following criteria:
  (a) Siting. Armoring shall be sited as far landward as practicable to minimize adverse impacts while still providing protection to the vulnerable structure..."
- (3) Marine Turtle Protection. Construction of armoring shall not be conducted during the marine turtle nesting season if the Department determines that the proposed construction will result in a significant adverse impact…

In the aggregate, the FDEP governing statute and rules prescribe that a permit for armoring <u>will</u> be issued if the structure to be protected is both eligible and vulnerable – subject to the siting criteria of Section 62B-33.051 (2). However, since 2008, FDEP has issued several variances for armoring structures to protect upland structures that are not eligible per FDEP rules; these variances cite a "hardship" generally attributable to erosion and the upland structure not being usable except with a seawall (FDEP, 2013). For any armoring permit issued by FDEP, the key - to minimize impacts to the beach dune system and sea turtle nesting habitat – is to construct the armoring "as far landward as practicable" as prescribed by Section 62B-33.051 (2) (a).

Seawalls

General:

In Florida and elsewhere, bulkheads are commonly referred to as seawalls. The primary purpose of a seawall is to prevent inland flooding, erosion, and damage from major storm events that occur with large, powerful waves. The primary purpose of bulkheads is to hold land or fill in place and prevent shore side losses; a secondary purpose of bulkheads is to protect the uplands from wave attack (CEM, 2008). For purposes of this White Paper, seawalls and bulkheads are considered synonymous.

As generally identified in the U.S. Army Corps of Engineers Coastal Engineering Manual (CEM, 2008):

- Seawalls can be vertical, sloped, or curved. Vertical seawalls are non-energy absorbing, while with a sloping surface or rubble mound, seawalls can absorb some energy during storm events. The front face may also be curved or stepped to deflect wave runup. Typical damage modes for seawalls include: toe scour leading to undermining; overtopping and flanking; rotational slide along a slip-surface below and shoreward of the seawall; and corrosion of any steel reinforcement.
- Seawalls are typically designed to be stable under soil loads associated with eroded design-storm conditions. To provide this stability, seawalls are commonly either cantilevered or anchored sheet piles. Cantilever bulkheads derive their support from ground penetration; therefore, the effective embedment length must be sufficient to prevent overturning. Toe scour results in a loss of embedment length and could threaten the stability of such structures. Anchored bulkheads are similar to cantilevered bulkheads except they gain additional support from anchors embedded on the landward side or from structural piles placed at a batter on the seaward side. For anchored bulkheads, corrosion protection at the connectors is particularly important to prevent failures. Gravity structures (where stability is attributable to the large mass of the structure and its frictional resistance) eliminate the expense of pile driving and can often be used where subsurface conditions support their weight or bedrock is too close to the surface to allow pile driving.
- The key design element for seawalls is the crest elevation to minimize overtopping from storm surge and wave runup.
- The ability of a seawall to resist wave attack is usually provided almost solely by the fill behind the seawall; if this material is lost, the seawall may collapse and fail under wave attack. Two common features of seawalls prevent or limit loss of backfill: (1) return walls at the alongshore ends of the seawall to prevent erosion of fill from behind the seawall, and (b) geotextile fabric to allow water – but not fines - to flow through, behind, or away from the seawall.

A seawall is typically designed to be stable under extreme storm conditions. Under FDEP rules [Section 62B-33.051 (2)(b)3], for seawalls in Florida, the design storm is limited to a 50-year return interval storm event. The required structural strength of a seawall is proportional to the square of the exposed height (H^2) of the seawall during design storm conditions, where the exposed height is the vertical distance from the top of the seawall to the beach berm.

The vertical faces of seawalls in Florida are most commonly and primarily comprised of sheet-piles – to minimize the footprint of the seawall and its associated adverse impacts upon the recreational beach and sea turtle nesting habitat. Sheet-piles are available in steel, aluminum, concrete, vinyl, reinforced fiberglass, wood and other materials; the materials of a seawall generally do not affect the impact of the seawall upon the beach-dune system.

For Figures 1a through 1c illustrate the three (3) types of seawalls commonly constructed in Florida:

- cantilever,
- laterally restrained by tie-rods and deadmen, and
- laterally restrained by soil anchors.

The soil loads on a seawall are associated with the "active earth pressure" of the soil pushing against the landward side of the seawall. Comparably, the buried portion of the seawall pushes against the soil to create "passive earth pressure" to offset the "active earth pressure" and to allow the seawall to remain stable.

As relected in Figure 2a, for a laterally-restrained seawall, the buried portion of the seawall pushes against the soil to create "passive earth pressure" against the seawall in the direction opposite to the direction of the "active earth pressure"; the lateral restraint also acts opposite to the direction of the "active earth pressure" and prevents rotation of the seawall. For stability in sandy (cohesionless) soils, a general rule-of-thumb for laterally restrained seawalls is that the sheet-piles must have an embedment depth (d) into the ground (on seaward side) a distance equal to the exposed height (H) – commonly referred to as "half-in and half-out".

As relected in Figure 2b, for a cantilever seawall, the buried portion of the seawall pushes against the soil to create "passive earth pressure" against the seawall in the direction opposite to the direction of the "active earth pressure"; however, to resist rotation, the seawall must extend further into the ground to produce an additional "passive earth pressure" acting in the same direction as the "active earth pressure. For stability in sandy (cohesionless) soils, a general rule-of-thumb for cantilever seawalls is that the sheet-piles must have an embedment depth (d) into the ground (on seaward side) a distance equal to 2X's the exposed height (H) – commonly referred to as "two-thirds-in and on-third-out".

For either a laterally restrained or cantilever seawall, the exposed height is a key feature that affects the required length of the sheet-piles and the required lateral restraint – for stability of the seawall. To reduce the exposed height that may occur due to wave scour at the toe of the seawall, a toe revetment might be constructed – as illustrated in Figure 1c. However, toe revetments should only be used when adverse impacts to sea turtle nesting habitat are avoided by placing the toe revetment below the water table or at least 3 feet below the beach berm.

Siting of Seawalls:

The engineering aspects of seawall siting are driven by soil reactions with the seawall, the lateral restraint, and the upland structure to be protected. As reflected in Figure 3:

- The soil retained landward of any seawall is inclined to slide along a "failure plane" (red-dashed line) such that a wedge of soil is retained by the seawall.
- For a laterally restrained seawall, the restraint (soil anchor or deadman) pushes against the soil with a corresponding "failure plane" (green-dashed line) of the restraint. For a tie-rod and deadman seawall, the deadman should be positioned sufficiently landward so that the failure plane of the deadman does not overlap with the failure plane of the seawall to ensure the deadman does not effectively push soil against the seawall, which is held by the seawall.
- It is also desirable that the slope (blue-dashed line) of the excavation needed to install the deadman does intersect the zone of influence of the foundation of the upland structure – particularly if the upland structure is not pile-supported.

For the three types of seawalls most common in Florida, the following summarizes the key siting considerations in design:

- Cantilever: A cantilever seawall can be constructed in close proximity to an upland structure – requiring only sufficient space for installation of the sheet-piles and as close as 5 feet seaward of the upland structure that is supported by a pile supported foundation. However, due to the absence of a lateral restraint, the top of a cantilever seawall is free to be displaced by the active-soil-pressure acting against the seawall; as a result, a cantilever seawall should be placed so the failure plane of the seawall is seaward of the zone of influence of an upland structure that is not supported by a pile foundation.
- Seawall with Soil Anchors: A seawall with soil anchors can also be constructed in close proximity to an upland structure – requiring only sufficient space for installation of the sheet-piles as close as 5 feet seaward of the upland structure with soil anchors installed by drilling beneath the upland structure - whether the upland structure is supported by a pile supported foundation or not. For a pile-supported upland structure, it is desirable to know the location of the piles to avoid impacts to the piles during the drilling and placement of soil anchors. However, due to the lateral restraint offered by the soil anchors, the top of the seawall is limited in displacement; as a result, a seawall with soil anchors can be placed so the failure plane of the seawall is within the zone of influence of an upland structure that is not supported by a pile foundation.
- Seawall with Tie-rods & Deadmen: A seawall with tie-rods and deadmen cannot be constructed in close proximity to an upland structure. Typically, more than 20 feet is needed between the seawall and upland structure for installation of the tie-rods and deadmen - whether the upland structure is supported by a pile supported foundation or not. The distance needed between a seawall and upland structure is proportional to the seawall's exposed height - the vertical distance from the top of the seawall to the beach berm.

To minimize adverse impacts to nesting turtles and the beach-dune system, seawalls should be sited "as far landward as practicable", as required by FDEP rules. Such siting frequently results in seawalls being discontinuous and/or not in a straight line; however, it is not necessary for seawalls to be continuous or in a straight line to yield structurally stable seawalls to protect upland structures and minimize the adverse impacts of seawalls.

Conclusions:

The following conclusions are offered relative to the siting of seawalls in Florida:

- For the three types of seawalls most commonly constructed in Florida:
  - A cantilever seawall or laterally restrained seawall with soil anchors can be constructed in the closest proximity to an upland structure.
  - A seawall with tie-rods and deadmen cannot be constructed in close proximity to an upland structure due to the space needed for installation of tie-rods and deadmen.
- If the upland structure is not pile-supported:
  - A cantilever seawall is not desirable in close proximity to the upland structure to be protected due to expected displacement of the top of the seawall and potential adverse settlement of the foundation of the upland structure.
  - A laterally restrained seawall is most appropriate to avoid settlement of the foundation of the upland structure.
- If the upland structure is pile-supported, any type of seawall is feasible, but a cantilever seawall or a laterally restrained seawall with soil anchors can be constructed the farthest landward - in the closest proximity to the upland structure.

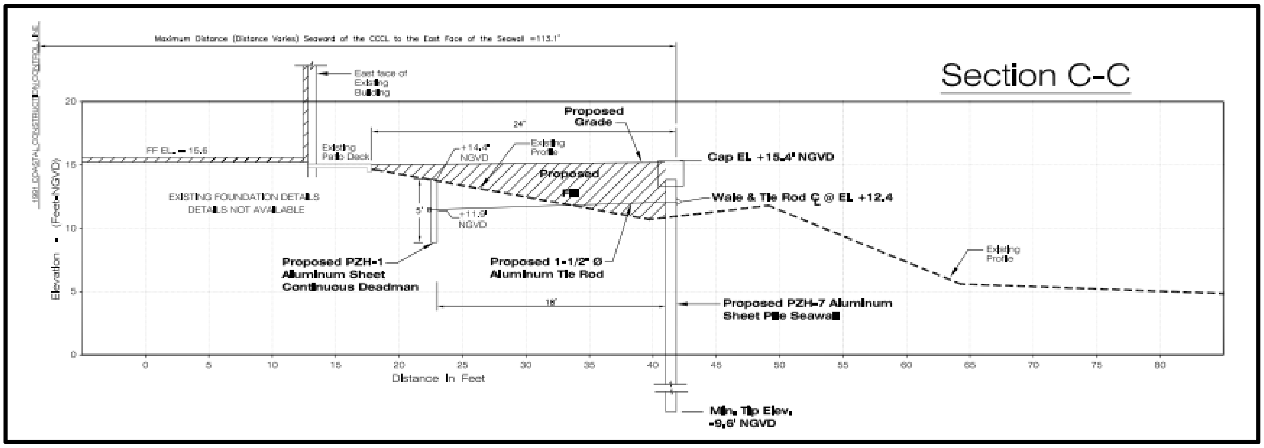

Figure 1a – Typical Cross-Section: Seawall with Tie-rod & Deadman

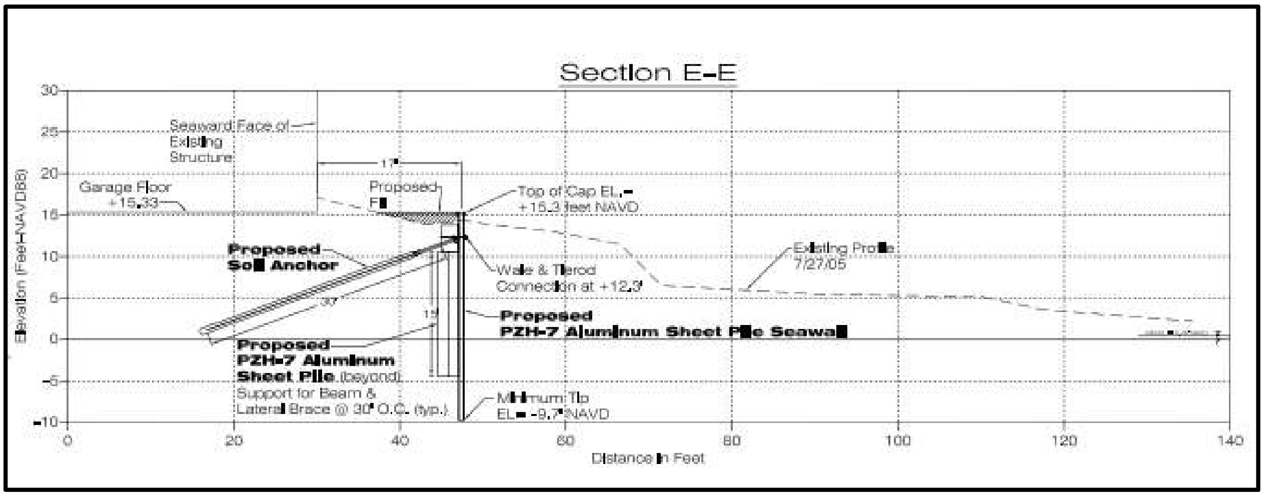

Figure 1b – Typical Cross-Section: Seawall with Soil Anchor

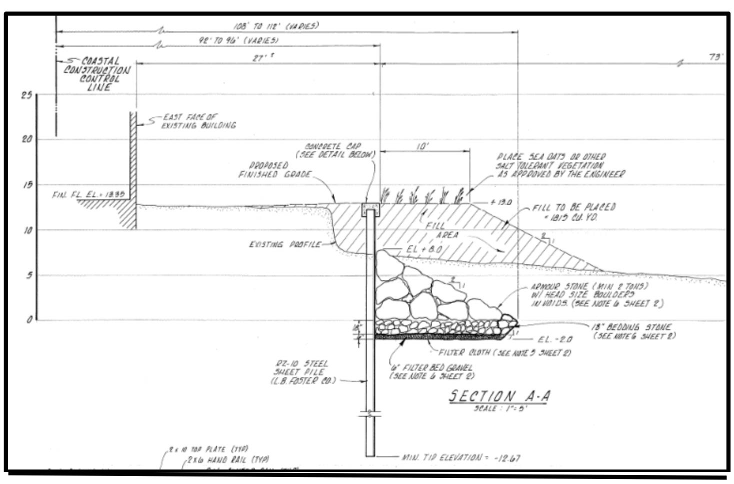

Figure 1c – Typical Cross-Section: Cantilever Seawall with rock toe-revetment

[Note: To avoid impacts to nesting turtles, toe revetments should be placed below the water table or at least 3 feet below the beach berm.]

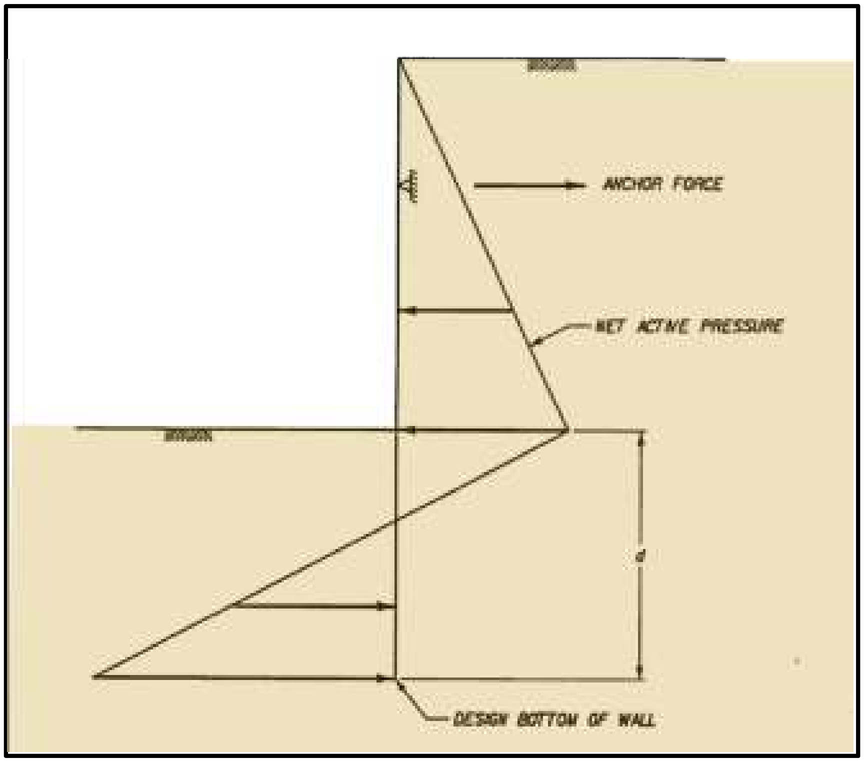

Figure 2a – Laterally Restrained Seawall - with Anchor

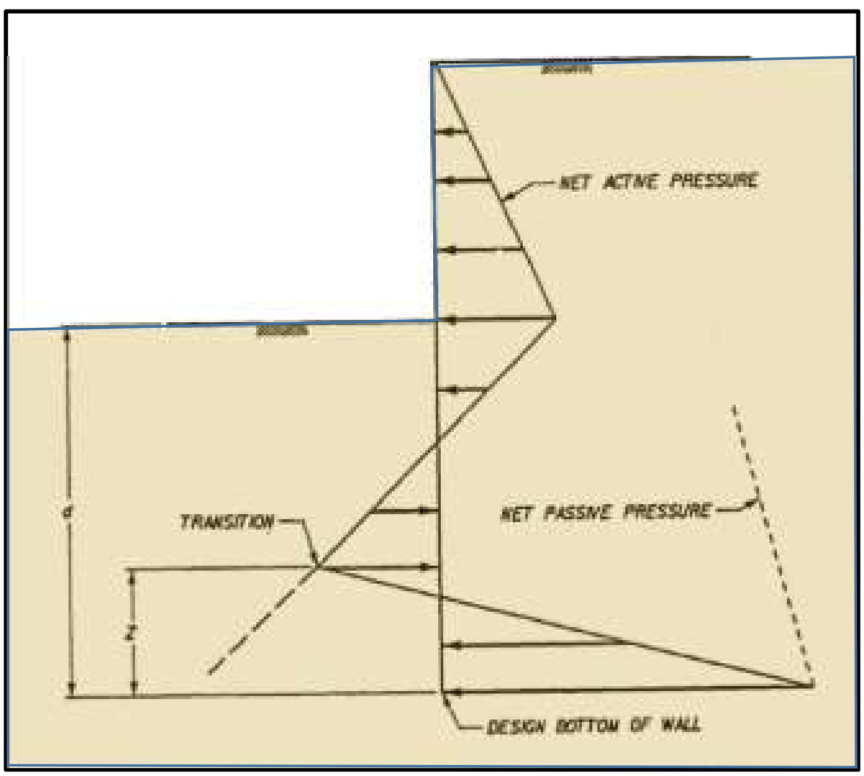

Figure 2b – Cantilever Seawall

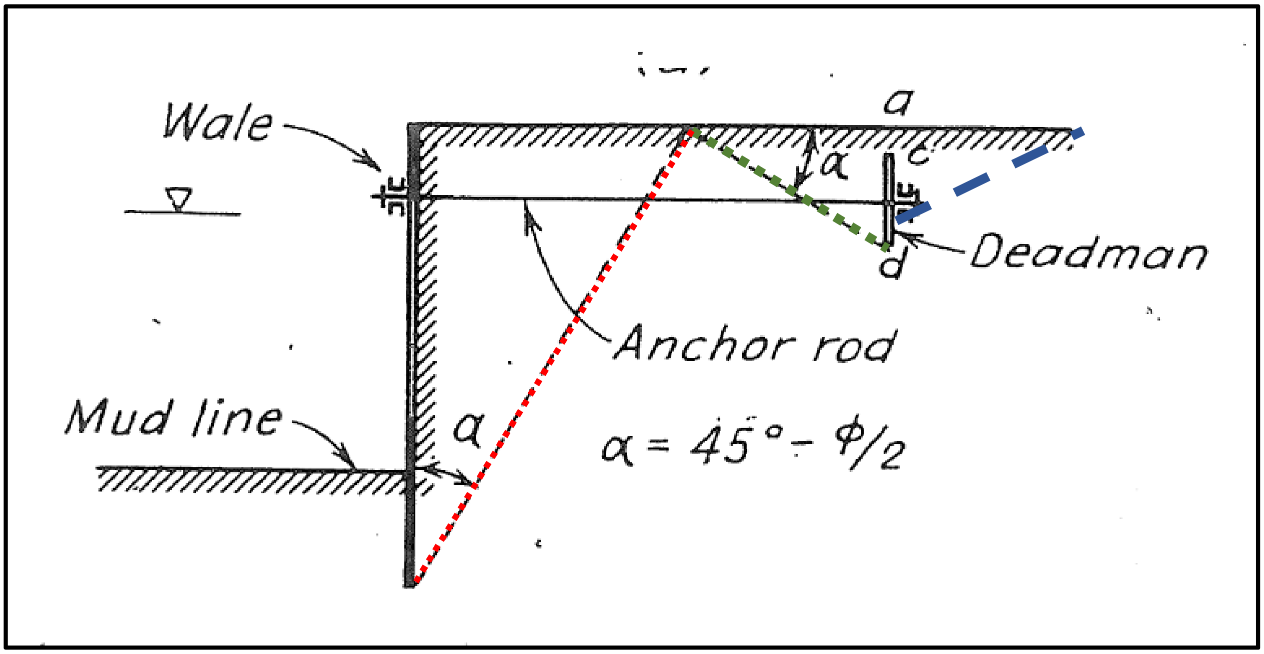

Figure 3 – Failure Planes (adapted from Peck et al)

References

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