Ground Anchor and Soil Nailing

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Ground Anchors

- Ground anchors are cement-grouted prestressed tendons installed in in-situ soil or rock by transmitting applied tensile loads into ground to stabilize earth retaining structures or to provide uplift resistance to structures.

- Ground anchors are suitable for a variety of geotechnical conditions. They can be used in soils, rocks, or other geomaterials. Different techniques may be used to install ground anchors in different geomaterials.

- Ground anchors may experience excessive creep deformations when they are installed in organic soil or soils with high plasticity. Caution should be exercised when ground anchors are used under such conditions.

Ground Anchors

- Ground anchors are also called tiebacks, which rely on long prestressed steel tendons bonded in a stable mass at a greater depth and distance to provide tensile resistance to unstable mass near wall or slope surface

- Tensile force induced by pre-stressing of steel tendons provides additional normal stresses to a critical slip surface so that shear strength along critical slip surface is increased thus resulting in a higher factor of safety against sliding

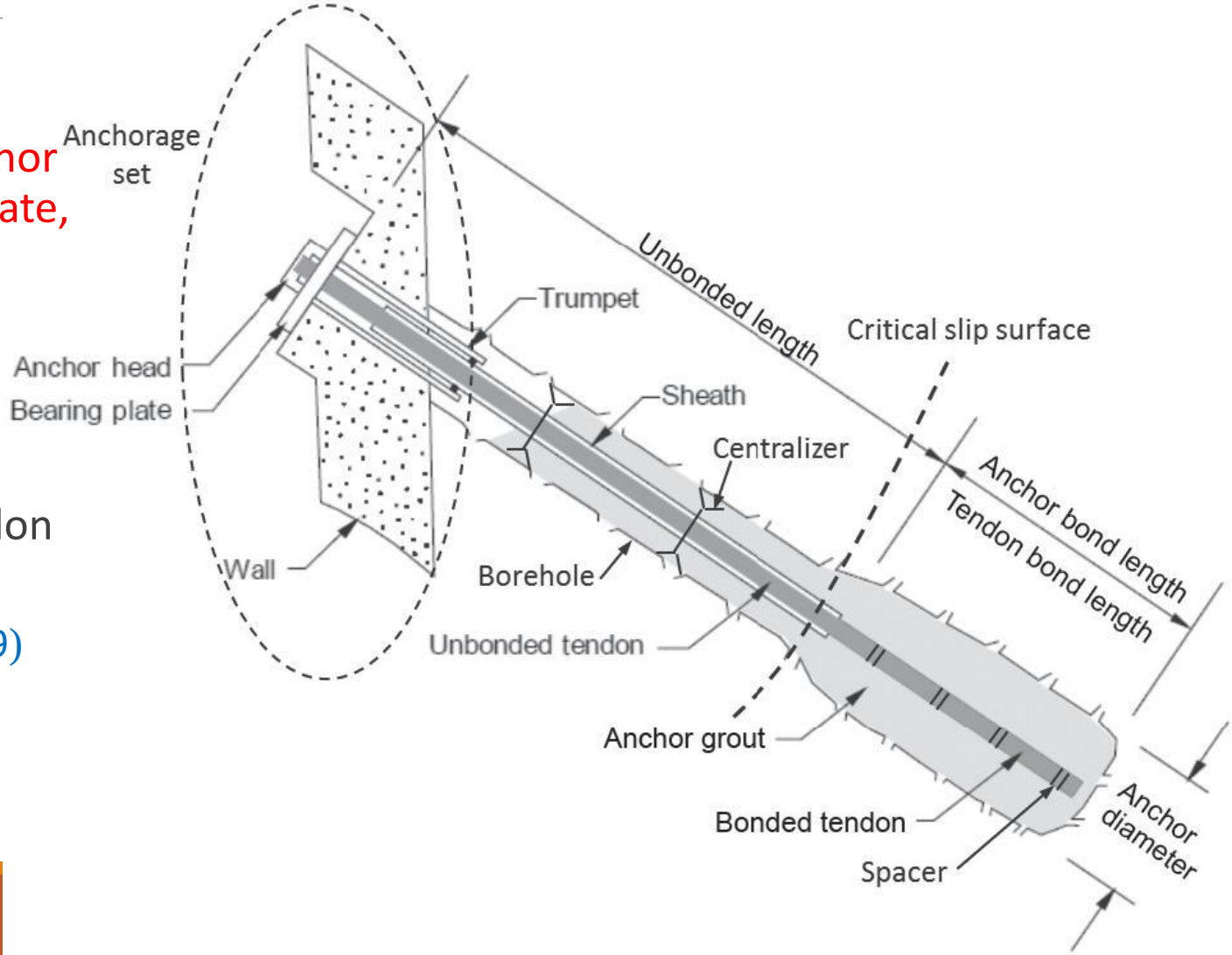
Basic Components of a Ground Anchor

Anchorage set, consists of an anchor head, a bearing plate, and a trumpet

Unbonded prestressing steel tendon

Bonded steel tendon with grout

(Sabatini et al., 1999)



Types of Ground Anchor

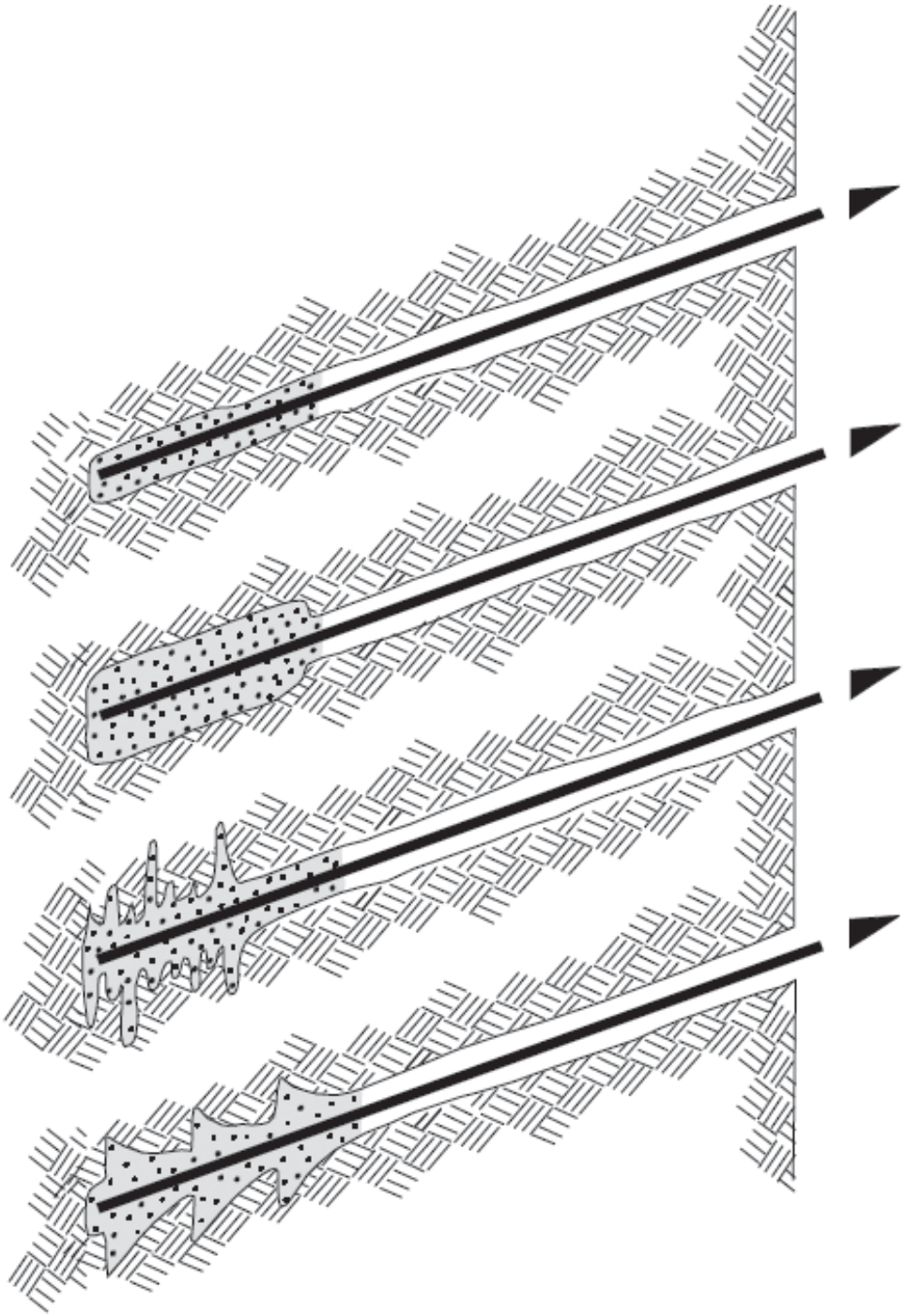
(Sabatini et al., 1999)

Type A: Straight shaft gravity grouted

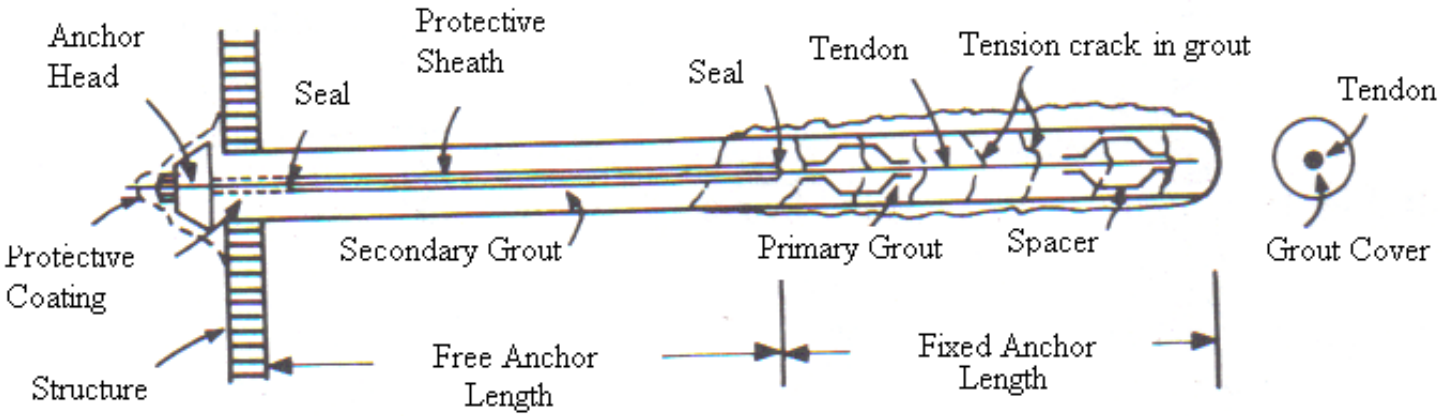
Type B: Straight shaft pressure grouted

Type C: Postgrouted

Type D: Underreamed

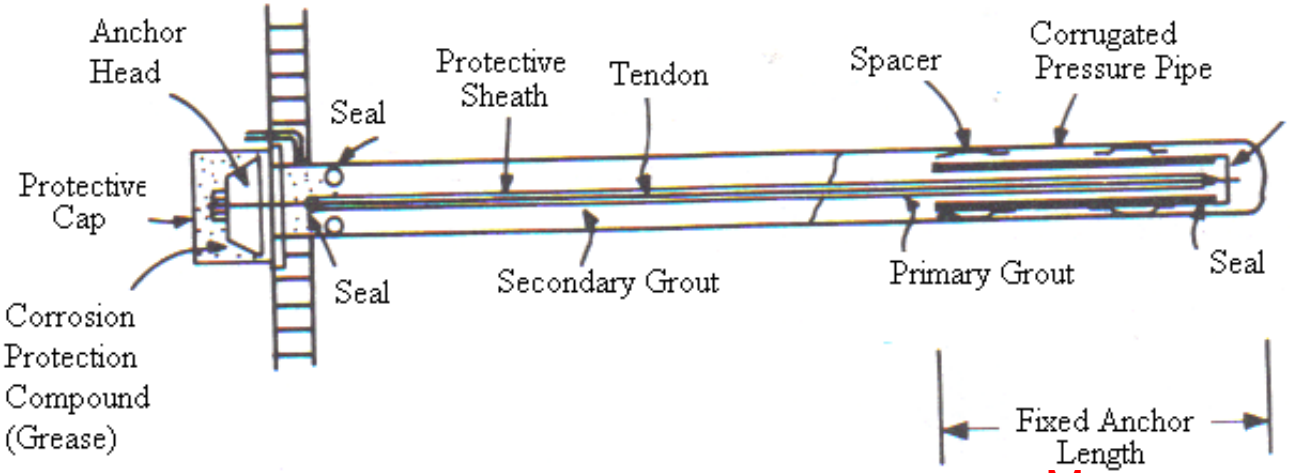


Types of Ground Anchor



TENSION ANCHOR

Mostly used for temporary structure
Service life 18 – 36 months



COMPRESSION ANCHOR

More expensive, therefore used for permanent protection.
Service life 75 – 100 years

(Hanna, 1982)

Installation of Ground Anchors

Installation procedure of different type of Ground anchor maybe different, but the general procedures are as follows:

- ✓ Drill a hole.
- ✓ Insert a steel tendon.
- ✓ Grout the hole within the bond length.
- ✓ Install the anchorage assembly.
- ✓ Prestress the steel tendon.

Construction of Ground Anchors

- ✓Drilling. Rotary, percussion, rotary/percussive, or auger drilling can be used to drill holes in soil or rock for ground anchors. The method of drilling should be selected to minimize the disturbance to soil or rock and nearby existing structures.

- ✓Inserting tendon. The tendon should be inserted into the drill hole to the desired depth and inclination angle.

- ✓Installing trumpet and anchorage. Depending on the method for corrosion protection, a specific material may be used around the unbonded lengths of the tendons, for example, corrosion inhibiting grease or grout. The bearing plate or the anchor head to be used for load testing should not contact with the corrosion protection material.

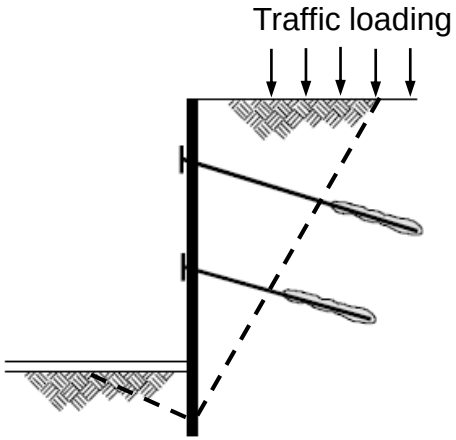
- ✓Grouting anchor. The grout is injected from the toe of the drill hole before or after inserting the tendon. The top of the grout should not be in contact with the bottom of the trumpet.

- ✓Testing and stressing the prestressed ground anchor. Each anchor should be subjected to stress for testing and evaluation. This is also part of quality assurance.

- ✓Lock-off. After the load testing, the anchor should be locked off by reducing the load to the lock-off load and transferring the load to the anchorage assembly. Typically, the lock-off load is 80% of the prestressed anchor service load.

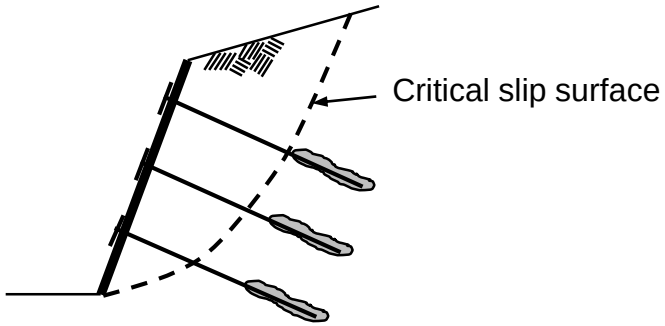
- ✓Cutting tendon protrusions. Extra tendon beyond the anchorage assembly should be cut by a saw.

Applications



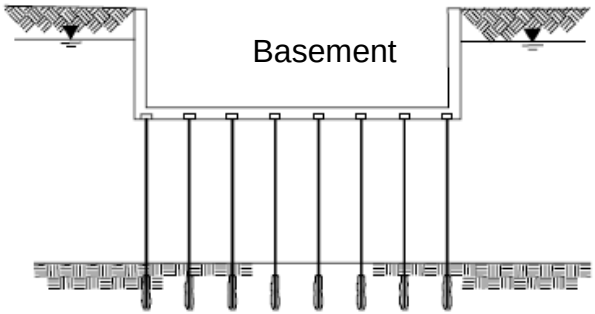
(a) Retaining Wall

Flexible anchored walls



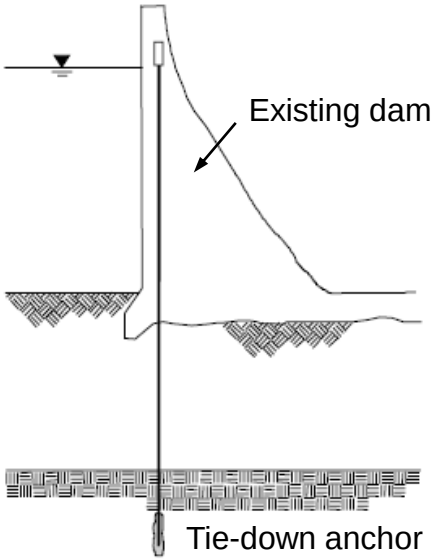
(b) Slope Stabilization

Ground anchor-stabilized slopes



Tie-down anchors

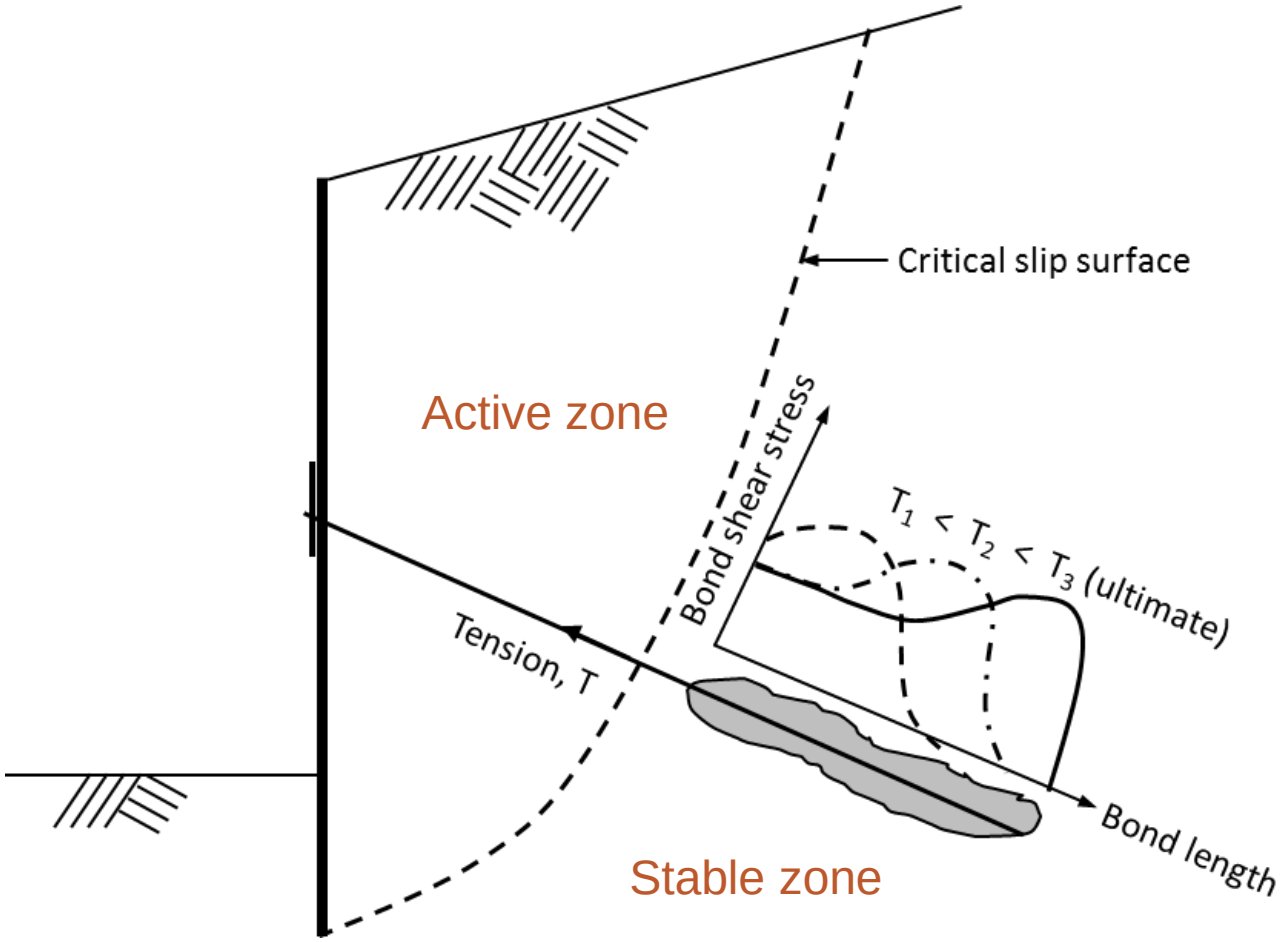
(c) Slab Anchorage under Uplift Force



(d) Concrete Dam Stabilization

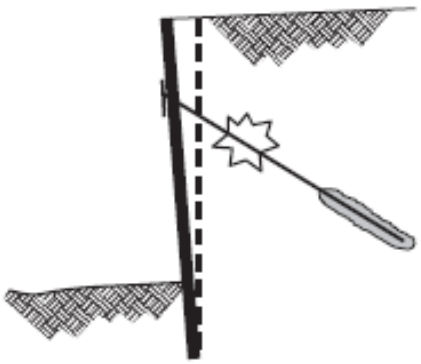
Modified from Sabatini et al.(1999)

Load Transfer Mechanism

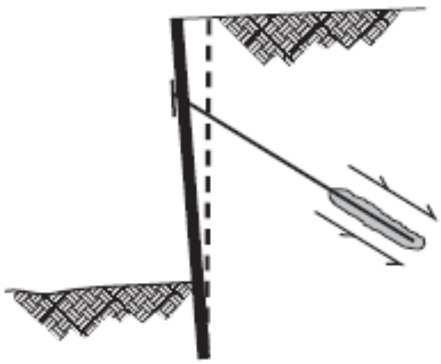


(Han, 2015)

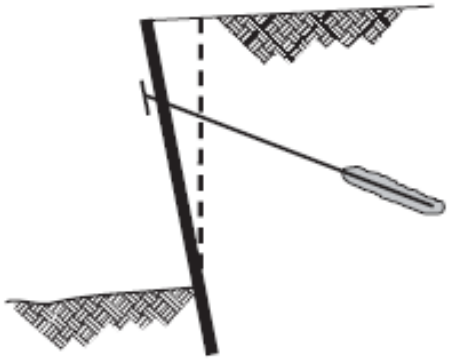
Possible Failure Modes



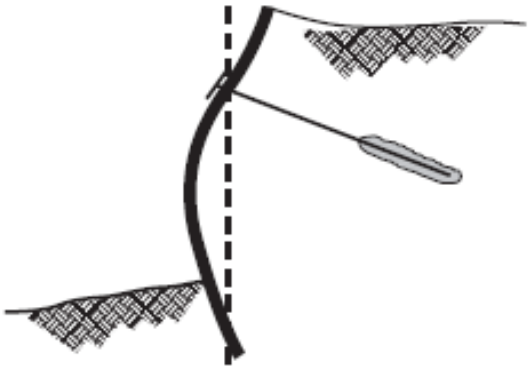
(a) Tensile failure of tendon



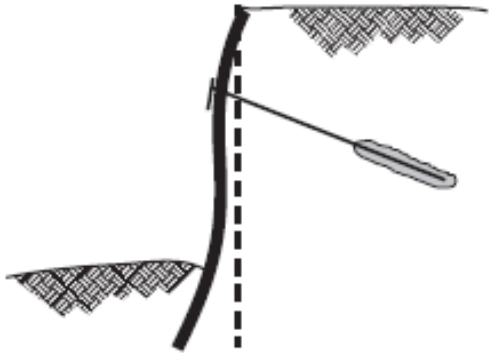
(b) Pullout failure of grout/ground bond



(c) Pullout failure of tendon/grout bond



(d) Failure of wall in bending

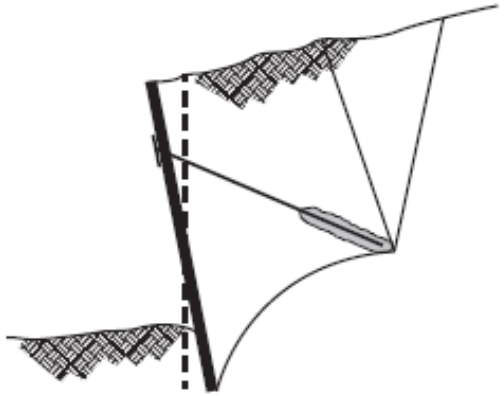


(e) Failure of wall due to insufficient passive capacity

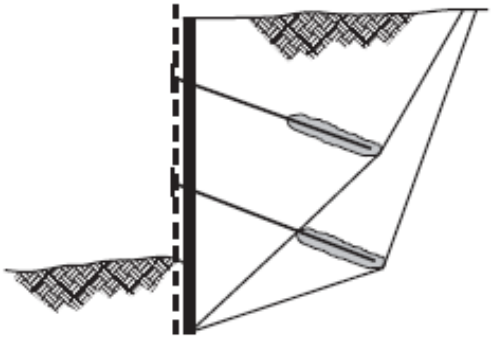
Possible Failure Modes (cont'd)

(f) Failure by forward rotation (cantilever before first anchor installed)

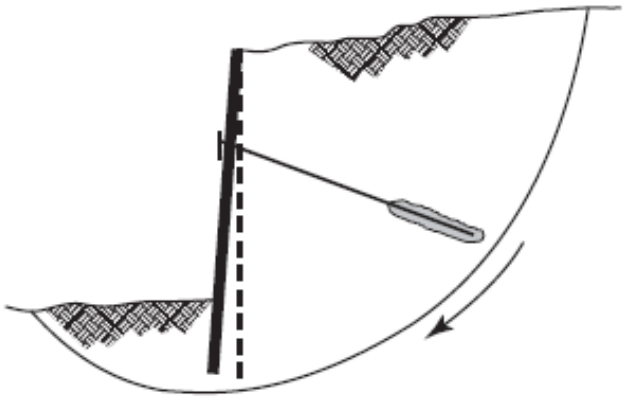
(g) Failure due to insufficient axial capacity



(h) Failure by overturning



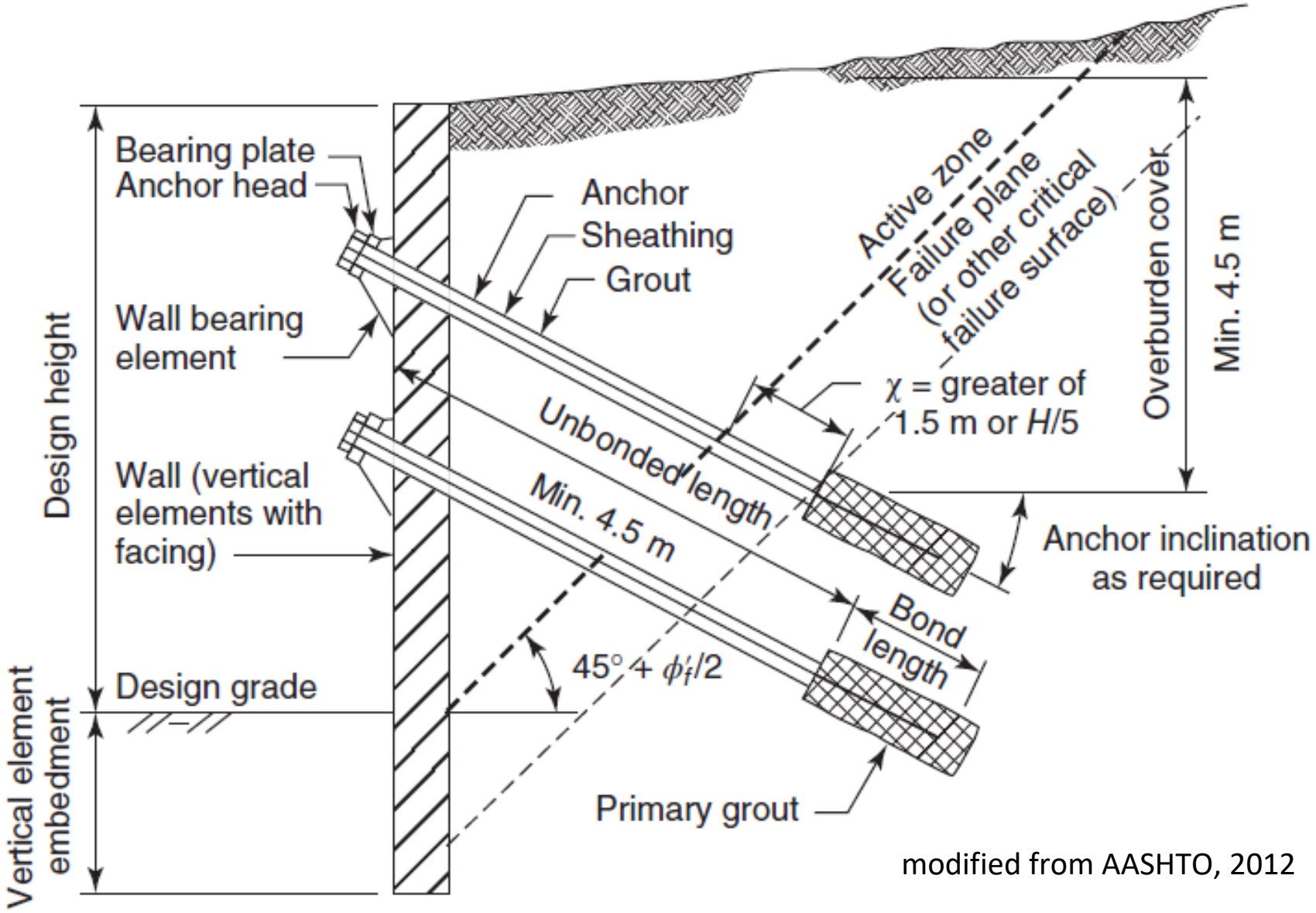
(i) Failure by sliding



(j) Rotational failure of ground mass

Sabatini et al., 1999

Typical design parameters



modified from AASHTO, 2012

Limitations of Ground anchor

- Ground anchors may be limited by objects in the ground (such as underground tunnels and utility lines) and the ground right-of-way space
- They may not work well in soft soils due to large and creep deformations
- Difficulties may arise in constructing watertight connections at the anchor-structural slab interface below the groundwater table

Stabilization of Rock Slope after Excavation

Anchored walls or slopes

Retaining wall for deep excavation with anchors in Singapore

Anchored walls or slopes

Application of Ground Anchor in Johor Bahru Malaysia

Soil Nailing

Soil Nails

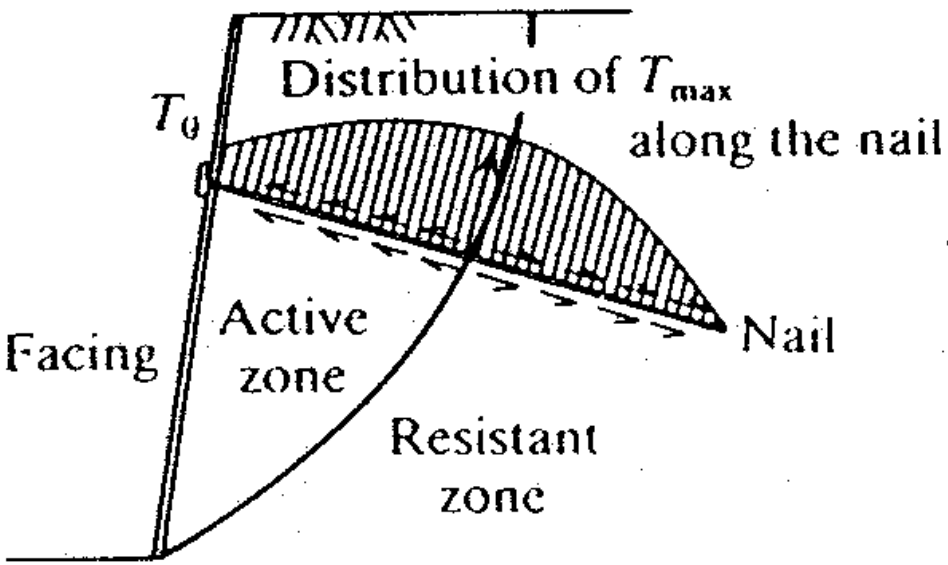
- Soil nailing is a technique to install closely spaced, passive structural inclusions to stabilize existing unstable ground due to the change of geotechnical conditions by nature and/or human activities.

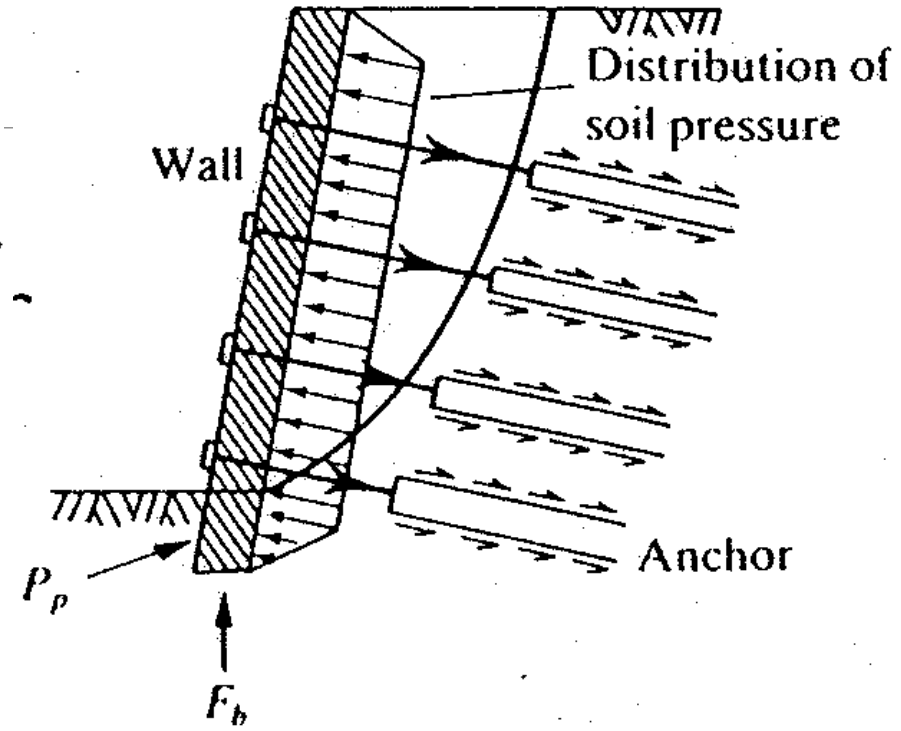
- Soil nailing relies on shorter but closely spaced, passive structural inclusions (nails) to stabilize existing unstable ground

- Tension in soil nails is mobilized during the soil movement induced by excavation

- Soil nailing is suitable for vertical or near vertical excavations in both soils and weathered rocks. It is also suitable for stabilizing steep unstable terrain of soils or weathered rocks.

Soil Nails vs. Ground Anchors





Nails are considerably smaller and shorter than anchors, and while anchors are pre-stressed after placement, nails are not (with few exceptions in which a very small pre-stress is applied), and do not pick up load until the soil mass deforms. Nails, like anchors, add shear resistance to the soil mass.

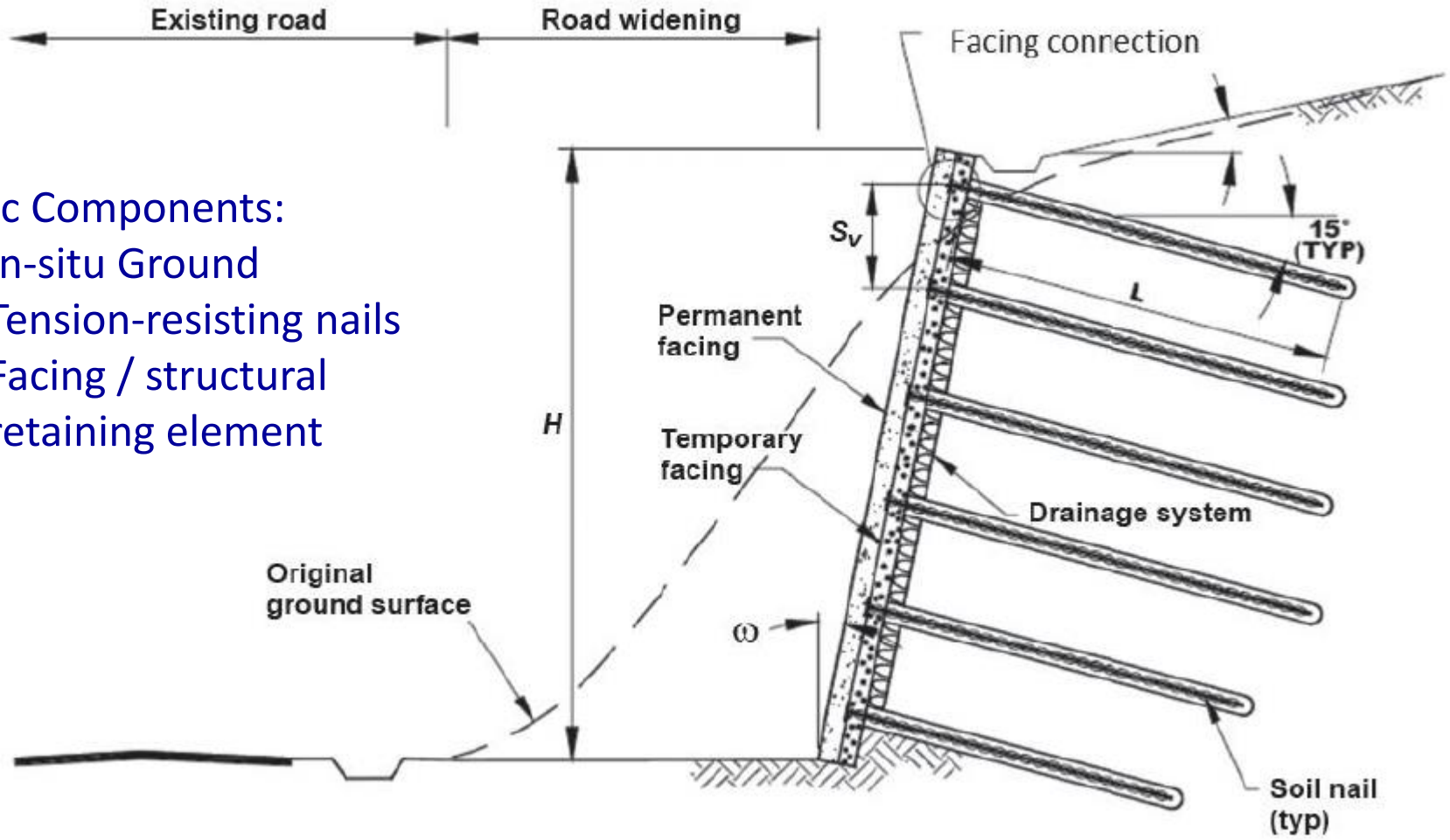
Soil Nails vs. Ground Anchors (cont'd)

- Soil movement is necessary for soil nails to be effective while the tension in the ground anchors is mobilized mostly by the prestressing and the limited soil movement adds more tension to the anchors
- Soil nails are bonded in both active and stable zones while ground anchors are only bonded in the stable zone.
- Soil nail transfers load along the entire length of the nail, whereas ground anchors are designed to transfer load only in the anchor zone behind the potential failure surface.
- Soil nails are often short and closely spaced while ground anchors are long and largely spaced

Typical Cross Section

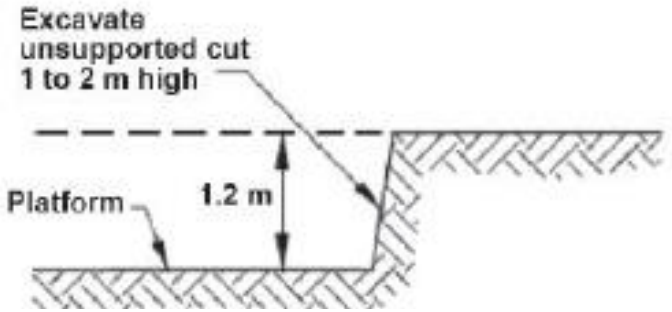
Basic Components:

1. In-situ Ground
2. Tension-resisting nails
3. Facing / structural retaining element

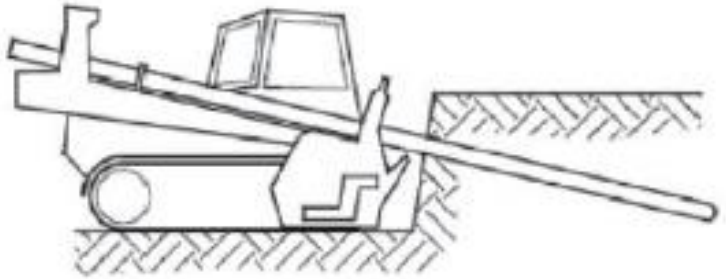


Lazarte et al., 2003

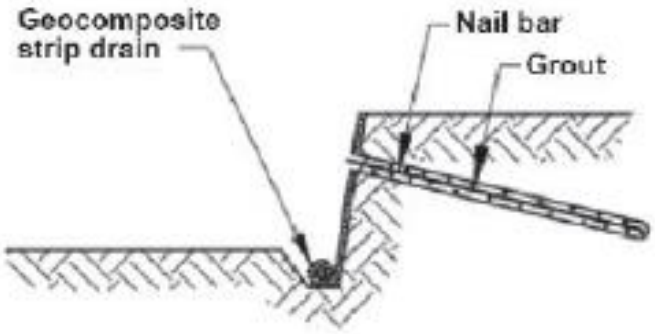
Construction of Soil Nails



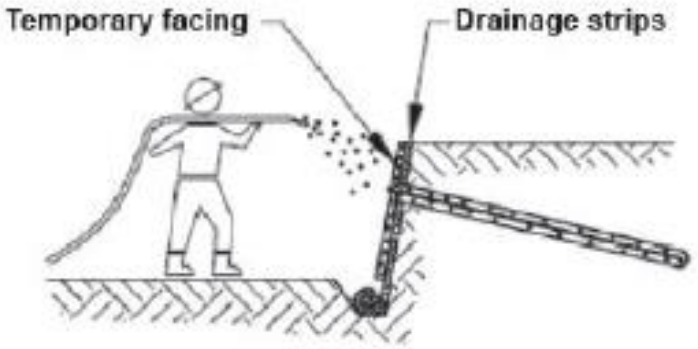
Step 1: Excavate small cut (1-2m)



Step 2: Drill nail hole



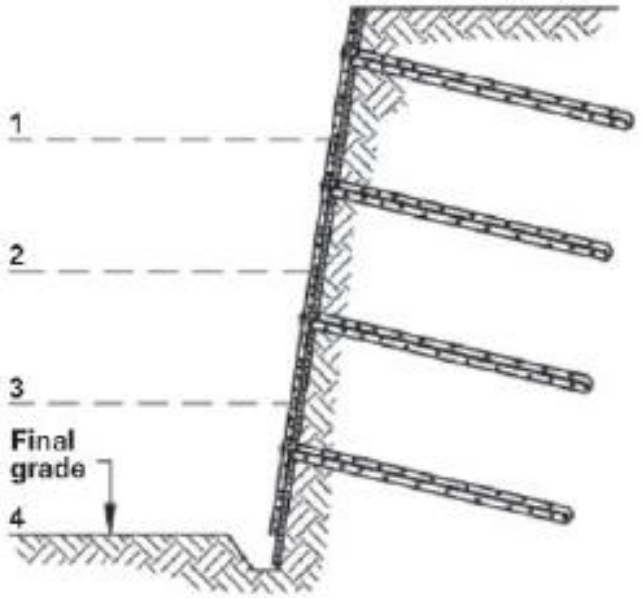
Step 3: Install and Grout nail (includes strip drain installation)



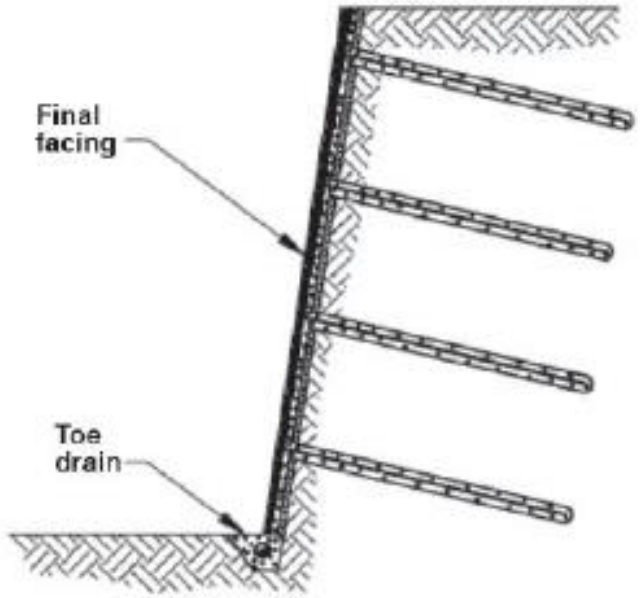
Step 4: Place temporary facing (includes shotcrete, reinforcement, bearing plate, hex nut, and washer installation)

Lazarte et al., 2003

Construction of Soil Nails (cont'd)



Step 5: Construction of subsequent levels



Step 5: Place final facing on permanent walls (include building of toe drain)

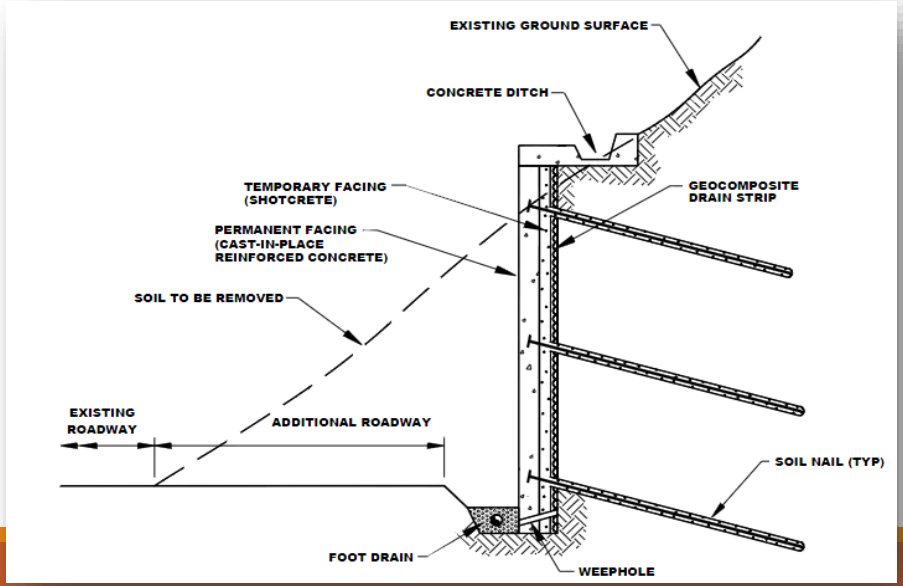
Lazarte et al., 2003

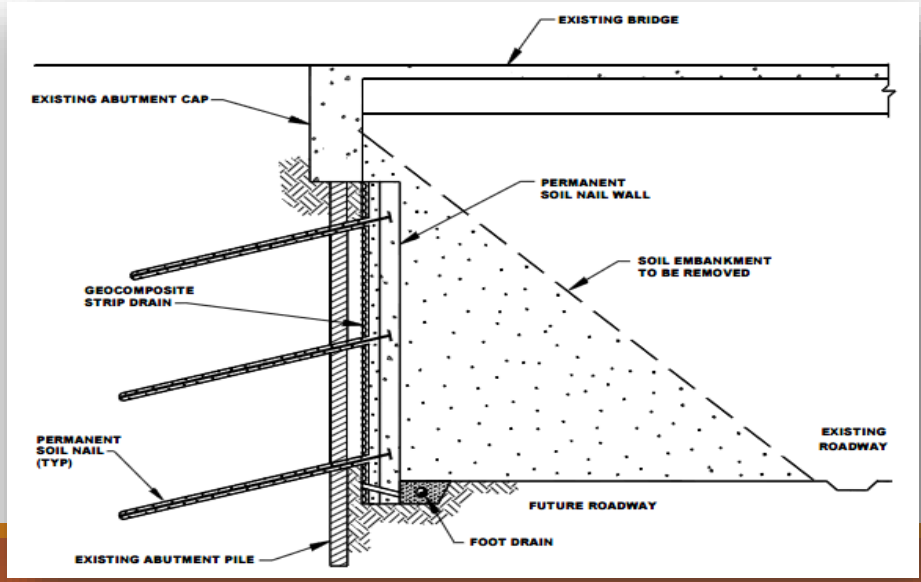
Soil Nailing Application

Soil nail wall in slope strengthening

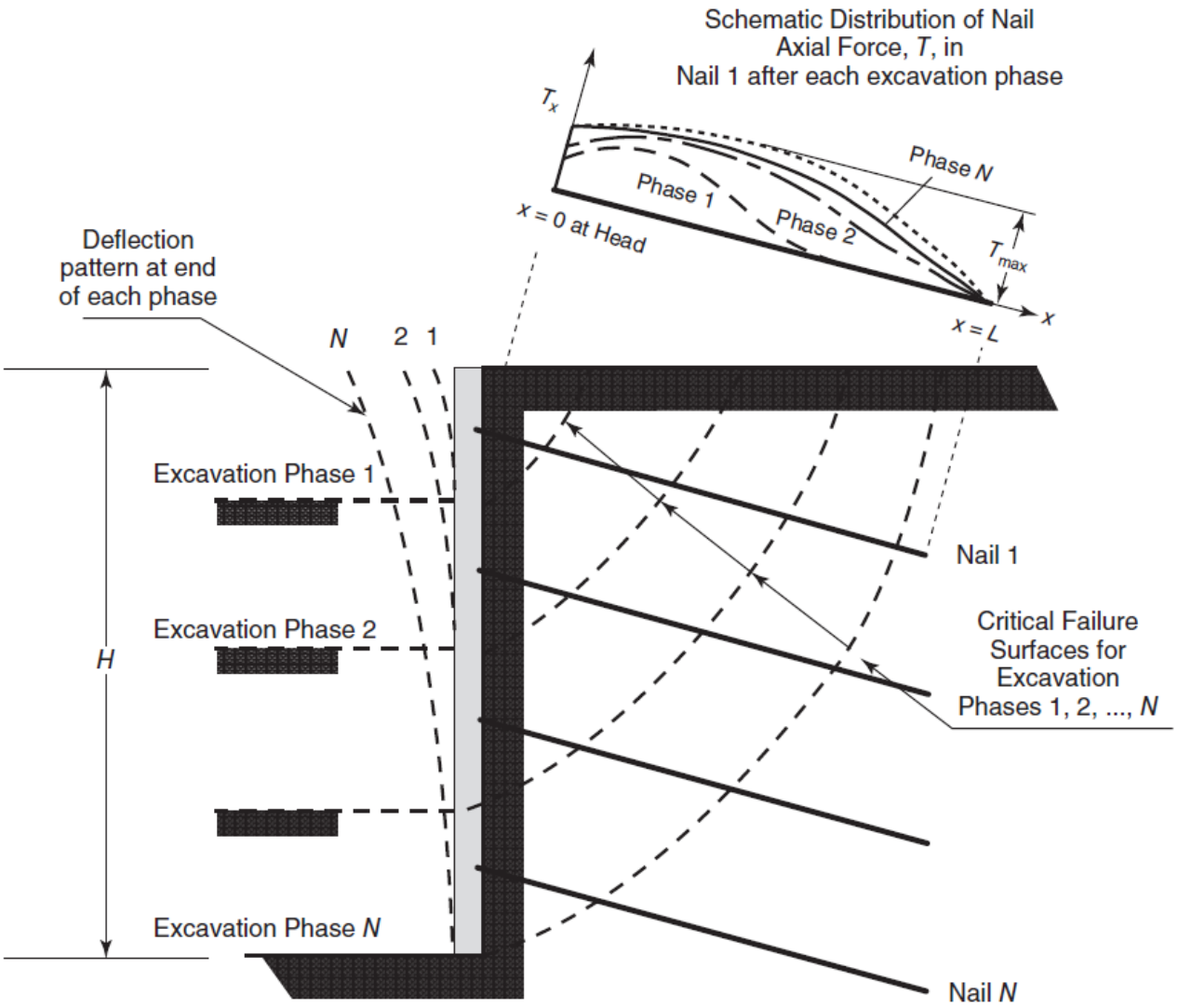
Soil nail wall in highway widening

Road widening under existing bridge





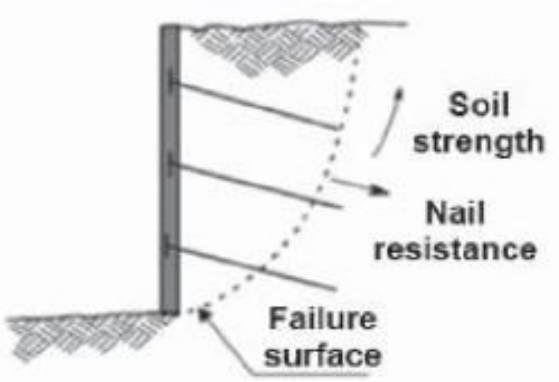
Load Transfer Mechanism



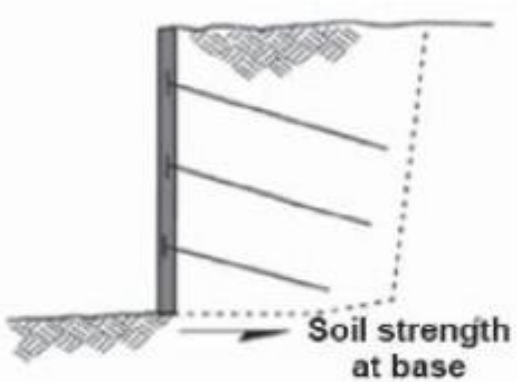
Elias et al., 2004

Modes of Failure

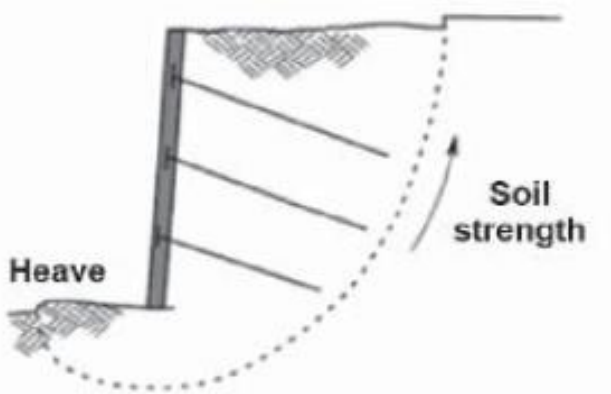
External Failure Mechanisms



(a) Compound Failure



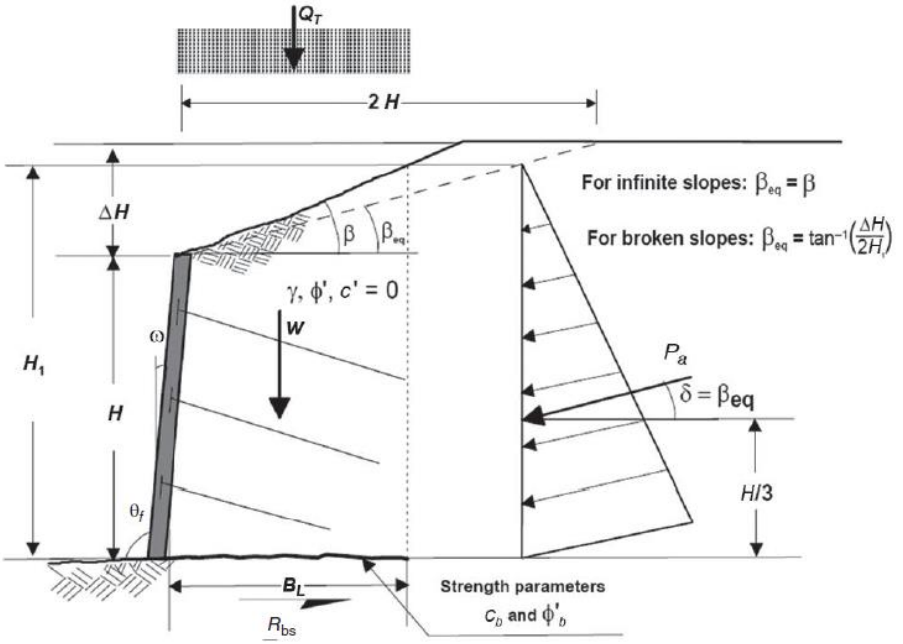
(b) Sliding Failure



(c) Global Failure

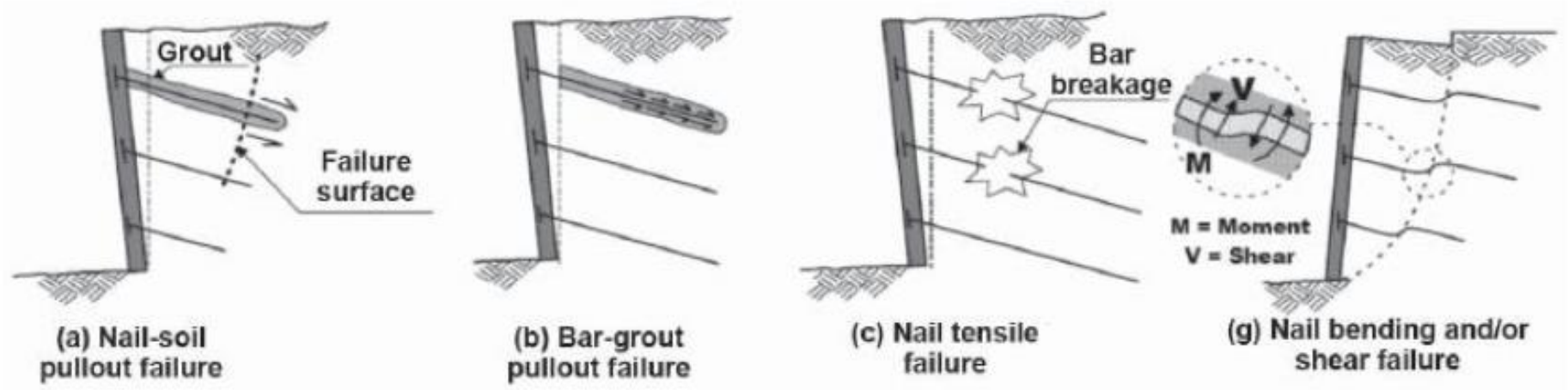
Slope stability analyses are required for case (a) and (c)

(b) External sliding on base

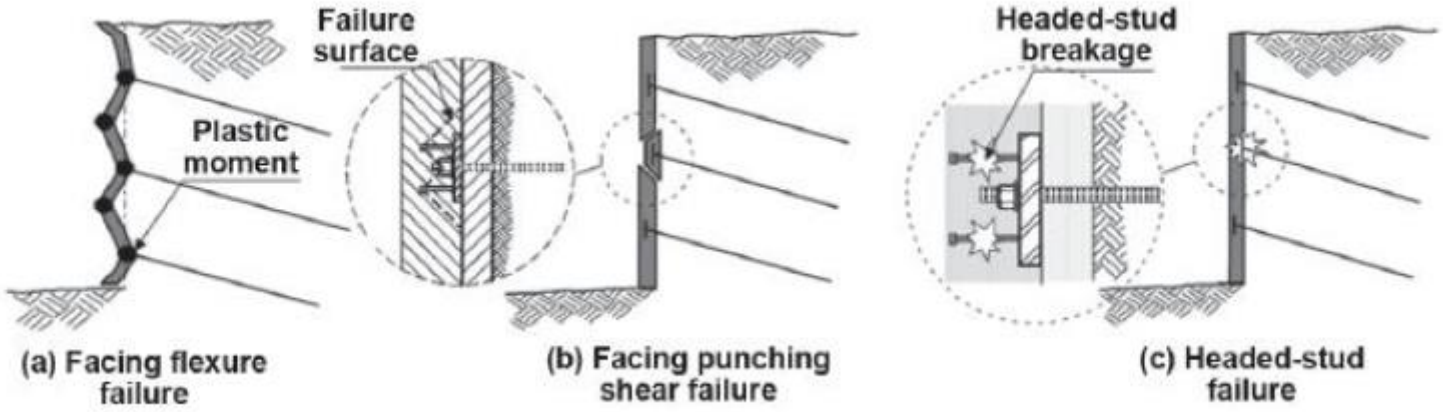


Modes of Failure

Internal Failure Mechanisms



Facing Failure Mechanisms



Typical Design Parameters

- Each nail has an influence area < 4m2
- Minimum soil nail spacing = 1.0m
- Minimum length of nail = 0.5*H* (*H* = height of wall)
- Drill hole diameter for grouted nails = 100–200mm
- Minimum nail inclination for gravity grouting and efficient nail tensile capacity = 15^{o}
- Recommended minimum factors of safety for different failure modes under static loading are as below:

Type of Analysis	Failure Mode	Symbol	Temporary Structure	Permanent Structure
External stability	Global stability (long term)	FS_G	1.35	1.5
	Global stability (excavation)	FS_G	1.2 to 1.3	1.2 to 1.3
	Sliding	FS_{SL}	1.3	1.5
	Bearing capacity	FS_{BC}	2.5	3.0
Internal stability	Nail pullout	FS_P	2.0	2.0
	Nail tensile failure	FS_T	1.8	1.8

Source: after Lazarte et al. (2003).

Lazarte et al., 2003

Completed Soil Nailed Wall