MSE Retaining Wall Design Considerations

by

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Geotechnical Branch

Wall Selection

CONCRETE BLOCK

MSE

TEMPORARY EARTH

SPREAD FOOTING

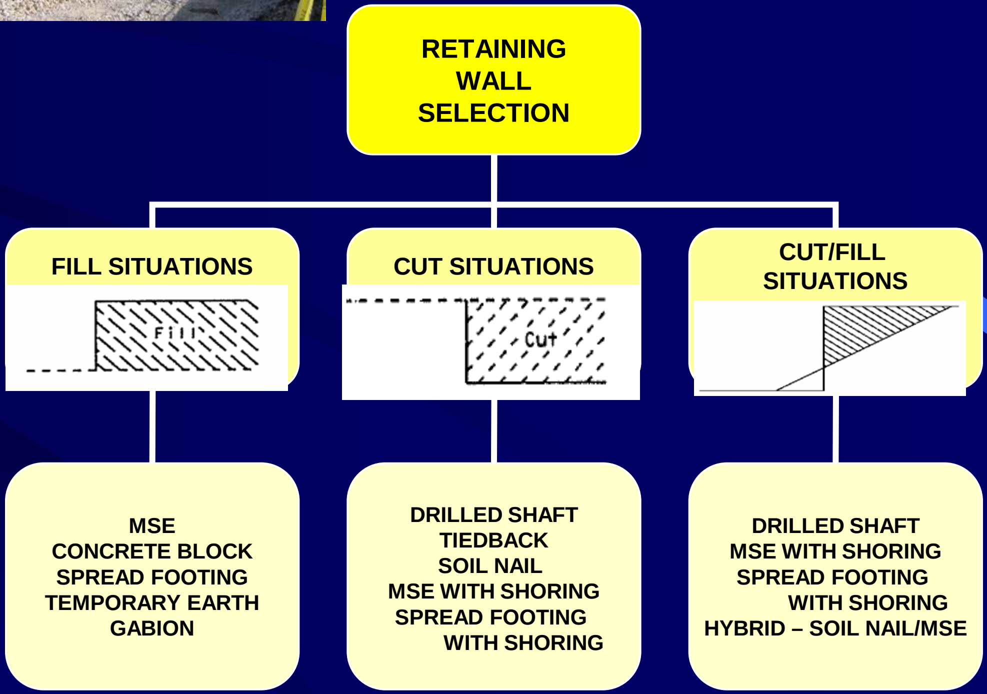
Gabions

Drilled Shaft

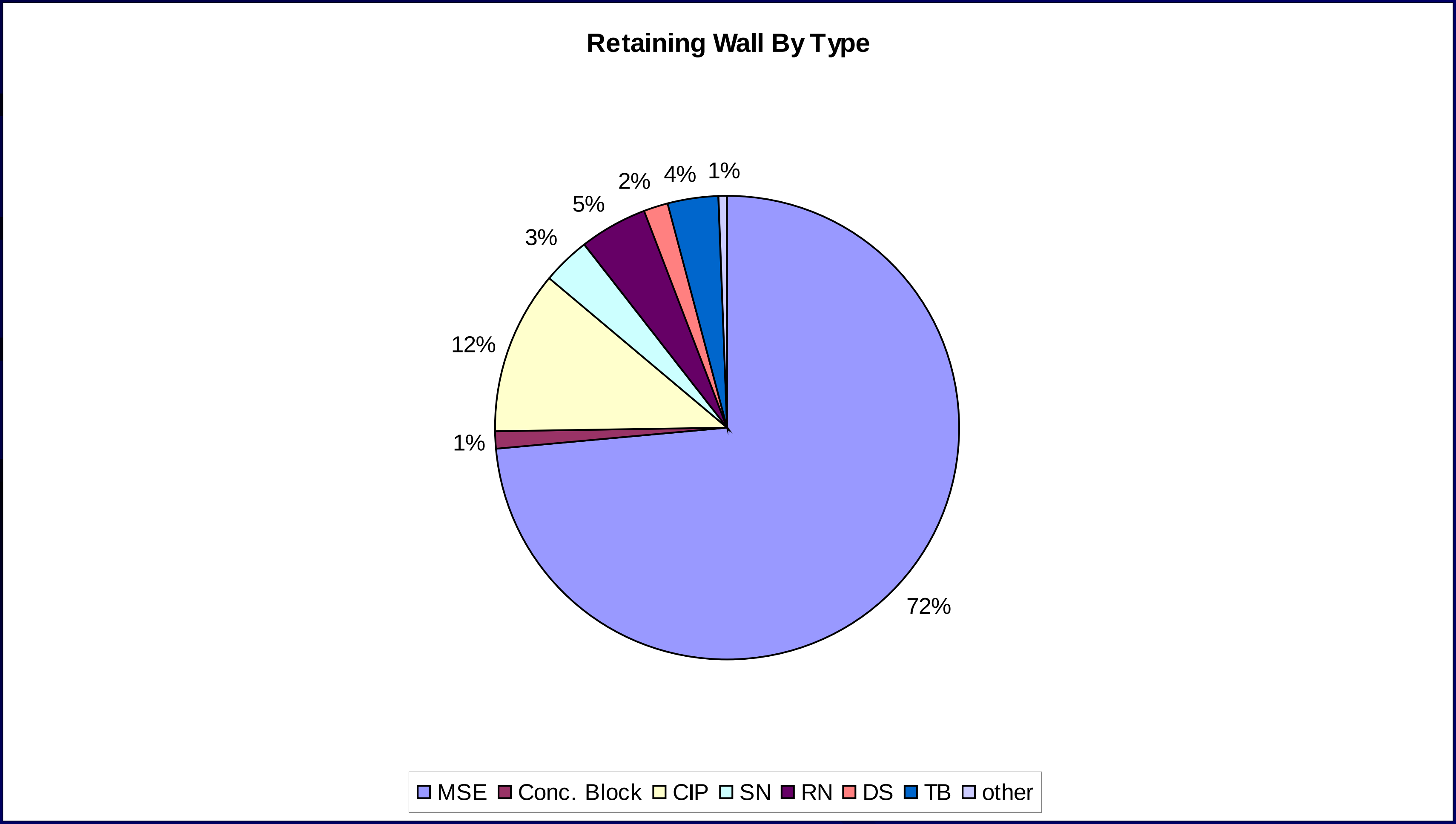
Soil Nail

Tiedback

Hybrid Walls – MSE/Soil Nail



Wall Usage by TxDOT
(August 2010 through September 2011)



Wall Usage by TxDOT

(August 2010 through September 2011)

Wall Type	Area (ft^2)	%
MSE	3,196,417	72
Concrete block (no r/f)	47,791	1
Cantilever drilled shaft	72,286	2
Soil Nailed	146,793	3
Rock Nailed	197,216	5
Tied-back	161,827	4
Spread footing	505,019	12
Other	22,389	1

Responsibility

The Project Engineer (Designer of Record) must ensure that the retaining wall system (design) selected for a given location is appropriate.

MSEW Construction Project Development

- External Stability Check by TXDOT or Consultant
  - Sliding
  - Limiting Eccentricity
  - Bearing Capacity
  - Global Stability
  - Settlement

- Internal Stability Check by Vendor
  - Tensile Resistance
  - Pullout Resistance
  - Face Element
  - Face Element Connection

- MSEW reinforcement and wall type is NOT specified at project bidding stage

MSEW Construction Project Development

- External Stability Check by TXDOT or Consultant
  - Sliding – FS $\geq$ 1.5
  - Limiting Eccentricity – e $\leq$ B/6
  - Bearing Capacity – FS $\geq$ 2.0
  - Global Stability – FS $\geq$ 1.3
  - Settlement

Assumed Soil Parameters (External Analysis)

	Material	Short- term		Long-term	
		c (psf)	ϕ (°)	c (psf)	ϕ (°)
Reinforced fill	Type A,B,D	0	34	0	34
	Type C	0	30	0	30
Retained backfill	controlled fill, PI<30	750	0	0	30 or PI- correlation
Foundation soil (Fill)	controlled fill, PI<30	750	0	0	30 or PI- correlation

Principal Modes of Failure - External

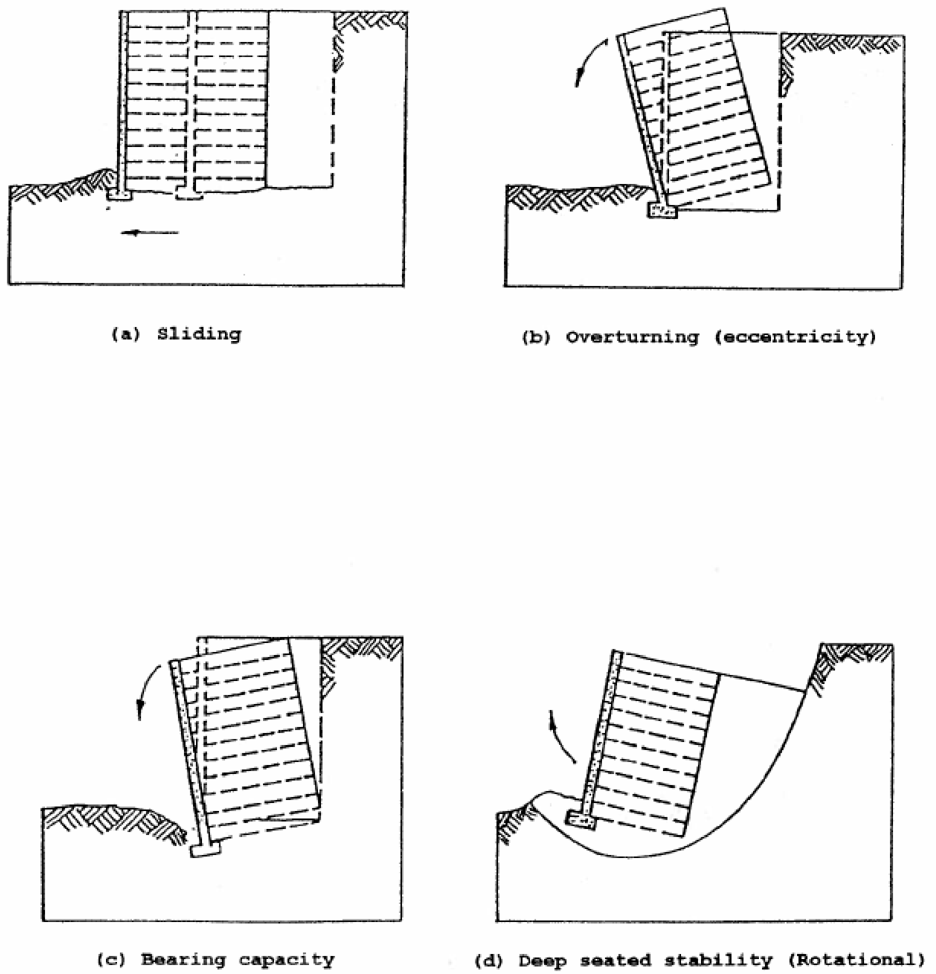


Figure 21. Potential external failure mechanisms for a MSE wall.

Principal Modes of Failure - External

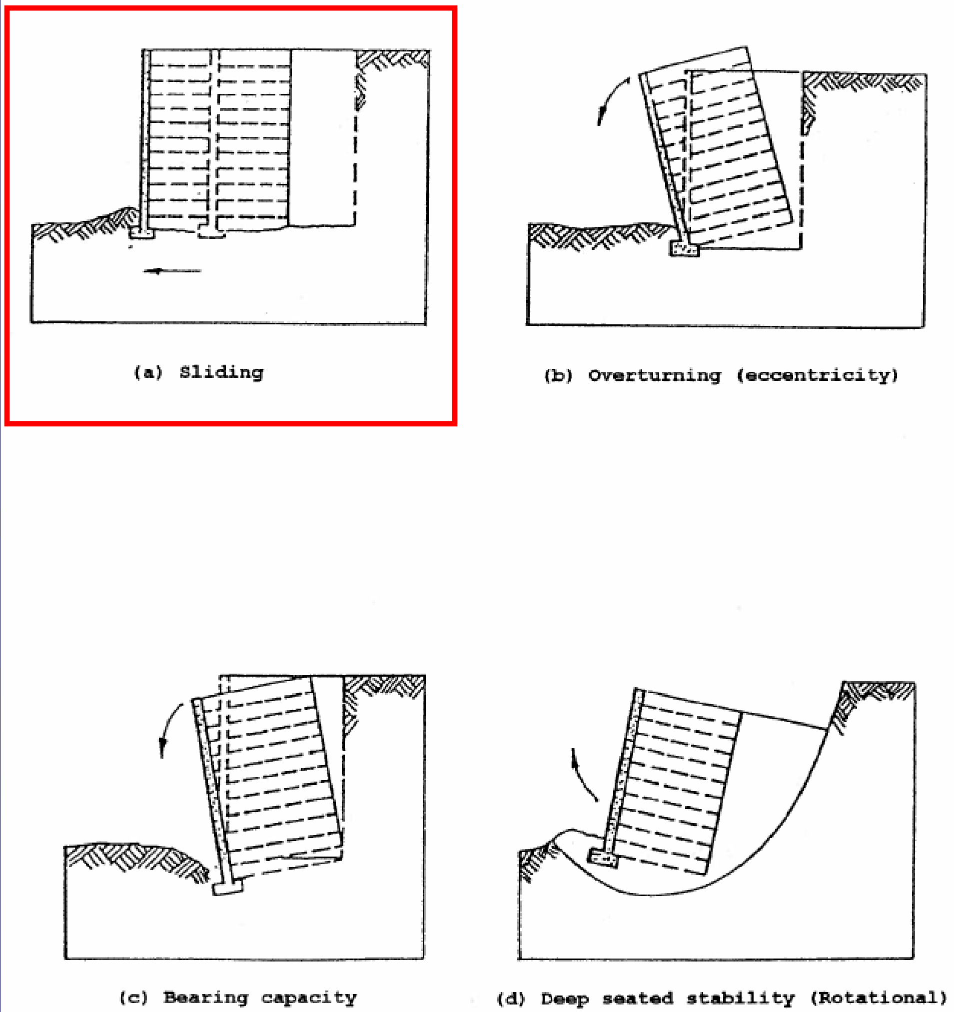
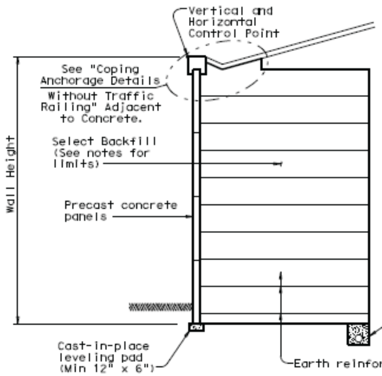


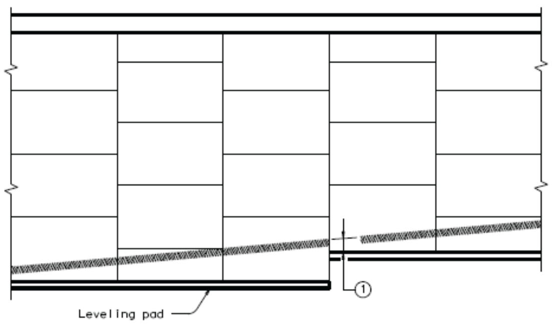
Figure 21. Potential external failure mechanisms for a MSE wall.

MSE WALL STANDARD



TYPICAL SECTION

(Wall at bottom of slope)

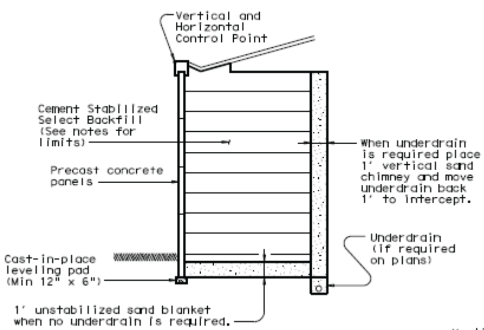


ELEVATION

1. Unless noted elsewhere in the plans, 1' minimum cover shall be provided from the top of leveling pad to finish grade.
2. Map of Texas emblem shall be formed into a wall panel next to each bridge abutment. The exact location of each emblem shall be approved by the Engineer. The cost of forming the emblems will not be paid for directly, but shall be incidental to the Item "Retaining Wall". The map of Texas shall be inset a minimum of ¾" into the face of the panel, and shall receive a smooth finish. The inset area shall be finished in a contrasting color as approved by the Engineer.
3. Precast coping shall be anchored to prevent rotation or displacement. Use these details to develop custom anchorage for precast copings. Details shall include coping reinforcement. Concrete flume (if required) shall be paid for separately from Item 423.
4.

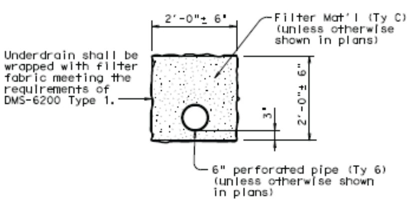
SELECT BACKFILL UNIT WEIGHT			
Type A, B & D	Unit Weight	Inernal Stability	External Stability
	105 PCF	Pullout	Sliding, Overturning, Eccentricity
	125 PCF	Rupture	Bearing

MAP OF TEXAS EMBLEM ②

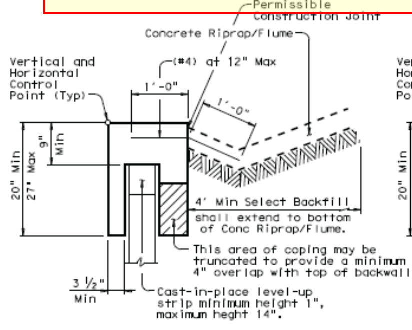


SPECIAL DRAINAGE PROVISIONS

(When cement stabilized backfill is used)

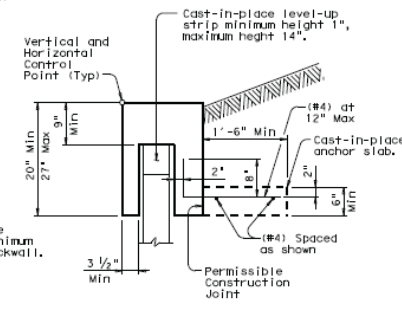


UNDERDRAIN DETAIL



ADJACENT TO CONCRETE

(Excluding Concrete Pavement)



ADJACENT TO SOIL

COPING ANCHORAGE DETAILS WITHOUT TRAFFIC RAILING ③

DESIGN PARAMETERS:

Design of retaining walls shall be based on the following design parameters unless stated elsewhere in the plans:

Random Backfill, Foundation Soil	unit weight = 125 pcf Ø = 30° c = 0 psf
Select Backfill	unit weight = See Table ④ Ø = 34° c = 0 psf
Cement Stabilized Select Backfill	unit weight = 125 pcf Ø = 45° c = 0 psf

Stress in steel and concrete shall be in accordance with current AASHTO Standard and Interim Specifications.

The minimum length of earth reinforcements shall be 8'-0" or 70% of the wall design height, whichever is greater. Wall height and wall design height may differ depending on project geometry and loading conditions.

STABILITY CRITERIA:

Factor of safety in sliding along the base of the structure shall be greater than or equal to 1.5.

Factor of safety in overturning shall be greater than or equal to 2.0.

The base pressure resultant shall fall within the middle third of the retaining wall.

The factor of safety against pullout of the earth reinforcements shall be greater than or equal to 1.5 at each level. Pullout resistance shall be determined from test data evaluated at ¾ inch strain.

CORROSION CRITERIA:

The earth reinforcement elements shall be designed to have a minimum design life of 75 years.

Stress calculations (rupture) shall be done on the calculated earth reinforcement section remaining after 75 years. Pullout calculations may be based on non corroded section.

GENERAL NOTES:

Section and elevation shown is for informational purposes only. Specific geometry is to be determined based on wall layouts and other plan information.

The select backfill specified for use within the mechanically stabilized earth volume shall extend horizontally from the back of the panels to the end of the earth reinforcements. The select backfill shall extend vertically from the top of the leveling pad or 4" below the lowest earth reinforcement, whichever is lower, to the top of panels.

The uppermost earth reinforcements shall be no more than 3.0' below the top of wall.

The lowest level of earth reinforcements shall be no more than 2.0' above the top of the leveling pad.

Minimum wire size for earth reinforcements shall be W7.0. If different longitudinal and cross wires are used in an earth reinforcement mesh, the smaller wire shall have at least 50% of the cross sectional area of the larger wire.

A maximum of four wire mesh configurations (wire sizes) will be allowed on a project. Each mesh configuration shall have a unique transverse bar spacing, differing from other configurations by a minimum of 3". Earth reinforcement lengths shall be stepped in increments no finer than 12".

Standard precast concrete panels shall have a maximum height of 6', and a maximum surface area of 50 sq ft. Top and bottom panels may exceed these limitations as necessary to achieve required wall grades. Maximum height of any panel shall be 7'-6". Minimum panel thickness shall be 5". Panels shall be arranged to provide offset horizontal joints.

An open joint shall be provided around the perimeter of the concrete panels. The nominal joint opening shall be between ⅜" and ¾". The joint configuration shall be such that the filter fabric or pad materials are not exposed at the wall face.

A one-piece corner panel shall be provided for wall angle changes of greater than 30 degrees. Butting of chamfered panels will be allowed for angle changes of 30 degrees or less.

Concrete coping shall be provided along the top of wall, at the vertical steps at bridge backwalls, and at other vertical steps along the top of wall. The joints between all coping segments shall be sealed to prevent infiltration of water into the retaining wall backfill. Sealing shall be in accordance with the DMS-6310 "Joint Sealants and Fillers", using Class 4 joint sealant.

Concrete must be Class "C".

All reinforcing steel must be Grade 60.

Coping and anchor slabs must be considered subsidiary to the Item "Retaining Wall".

DISCLAIMER:
The use of this standard is governed by the "Texas Engineering Practice Act". No warranty of any kind is made by TxDOT for any purpose whatsoever. TxDOT assumes no responsibility for the conversion of this standard to other formats or for incorrect results or damages resulting from its use.

Texas Department of Transportation
Bridge Division

MECHANICALLY STABILIZED EARTH RETAINING WALL

RW(MSE)

FILE: rwstde01.dgn	DN: TxDOT	CK: TxDOT	DW: JGD	CK: MJG
©TxDOT March 2010	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS 04-11: Added Table & Corrosion Criteria.	COUNTY	CONTROL	SECT	JOB / HIGHWAY


U-HAUL

External Stability - Sliding

DESIGN PARAMETERS:
Design of retaining walls shall be based on the following design parameters unless stated elsewhere in the plans:

Random Backfill, Foundation Soil	unit weight = 125 pcf Ø = 30° c = 0 psf
Select Backfill	unit weight = See Table (4) Ø = 34° c = 0 psf
Cement Stabilized Select Backfill	unit weight = 125 pcf Ø = 45° c = 0 psf

Stress in steel and concrete shall be in accordance with current AASHTO Standard and Interim Specifications.
The minimum length of earth reinforcements shall be 8'-0" or 70% of the wall design height, whichever is greater. Wall height and wall design height may differ depending on project geometry and loading conditions.

(4)

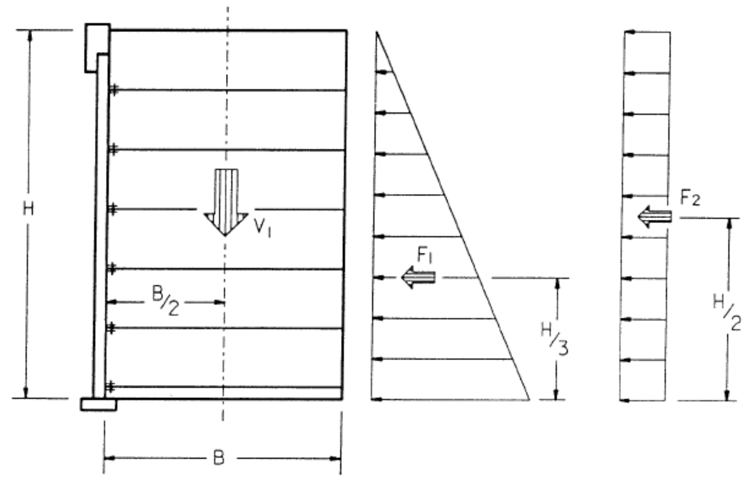
SELECT BACKFILL UNIT WEIGHT			
Type	Unit Weight	Inernal Stability	External Stability
A, B & D	105 PCF	Pullout	Sliding, Overturning, Eccentricity
	125 PCF	Rupture	Bearing

FORCE DIAGRAM FOR FACTOR OF SAFETY CALCULATIONS

WEIGHT OF RETAINED EARTH MASS ~ V_1

EARTH PRESSURE FROM RANDOM BACKFILL ~ F_1

EARTH PRESSURE FROM TRAFFIC SURCHARGE ~ F_2



CALCULATIONS

$V_1 = \gamma_s B H$

γ_s = UNIT WEIGHT OF SELECT BACKFILL
B = MESH LENGTH
H = WALL HEIGHT

$F_1 = \frac{1}{2} \gamma_R H^2 Ka$

γ_R = UNIT WEIGHT OF RANDOM BACKFILL
Ka = COEFFICIENT OF ACTIVE EARTH PRESSURE FOR RANDOM BACKFILL

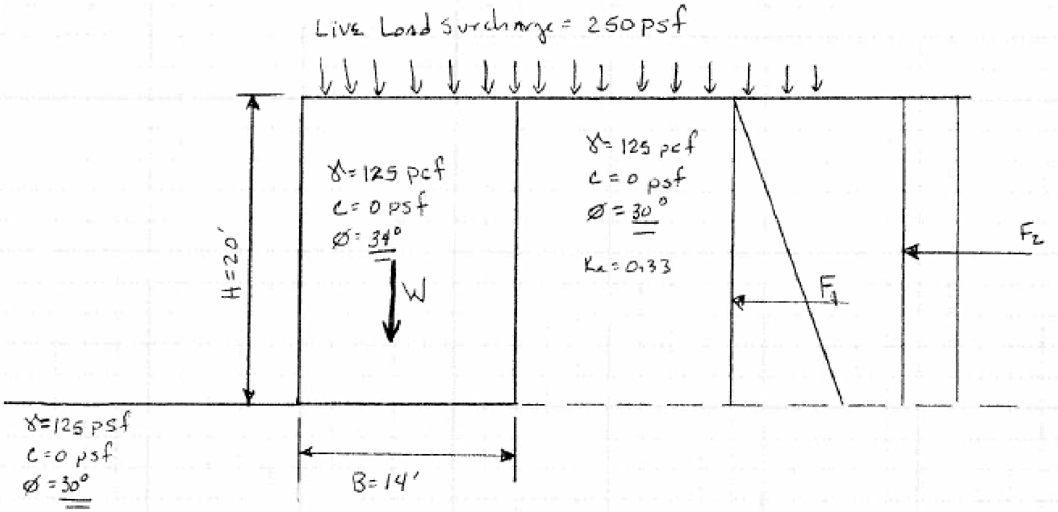
$F_2 = \gamma_R h H Ka$

h = DEPTH OF TRAFFIC SURCHARGE (USUAL 2')

$$\text{FS – Sliding} = \frac{V_1(\tan(\text{phi}))}{F_1 + F_2}$$

105/125 = 0.84 or a 16% reduction in sliding resistance

Sliding Analysis



W = (20')(14')(125pcf) = 35,000 lb = 35 kips

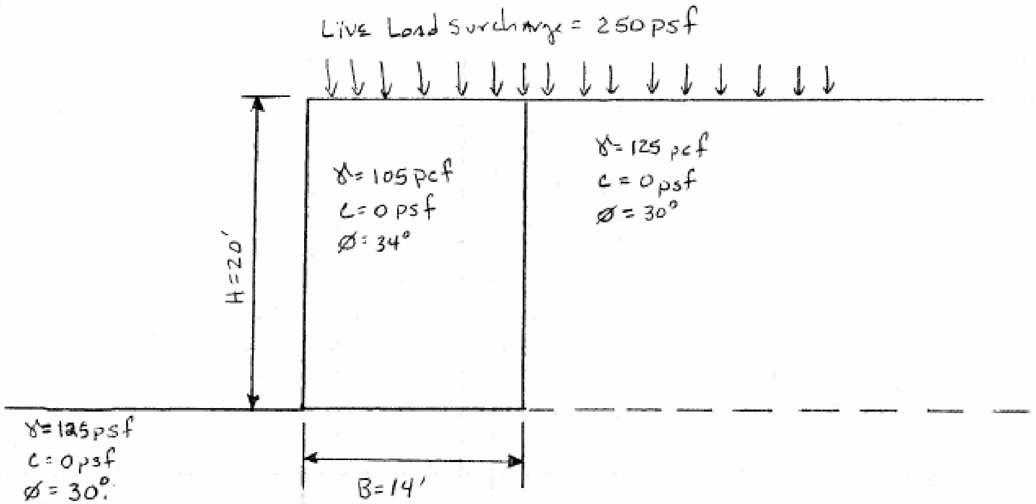
$F_1 = (0.33)(1/2)(20')^2(125) = 8250 \text{ lb} = 8.25 \text{ kips}$

$F_2 = (0.33)(20')(250 \text{ psf}) = 1650 \text{ lb} = 1.65 \text{ kips}$

$$\text{Factor of Safety} = \frac{\text{Resisting}}{\text{Driving}} = \frac{35 \text{ kips } (\tan(30))}{8.25 \text{ kips} + 1.65 \text{ kips}}$$

$$= \frac{20.2 \text{ kips}}{9.9 \text{ kips}} = 2.04 > 1.5 \quad \text{OK}$$

Sliding Analysis



$$W = \left(\frac{35\text{ kips}}{125\text{ psf}}\right)(105\text{ psf}) = 29.4\text{ kips}$$

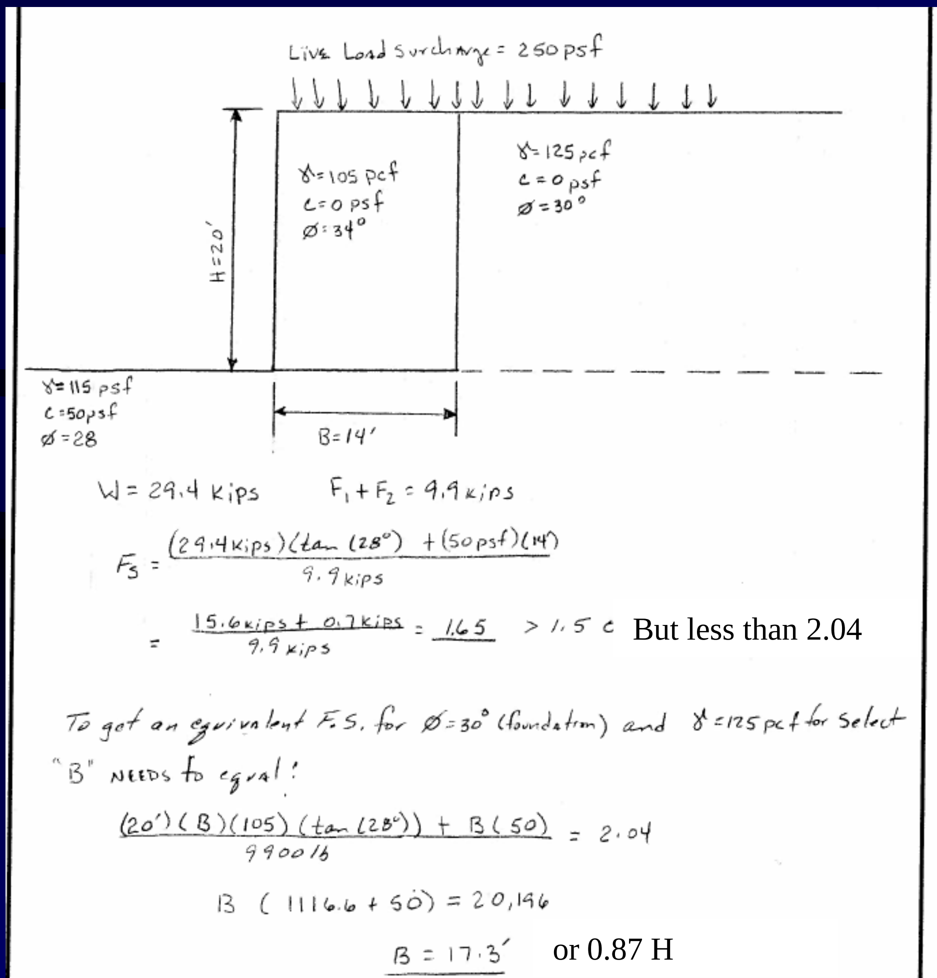
$$F.S. = \frac{29.4\text{ kips}\,(\tan(30))}{9.9\text{ kips}} = 1.71 > 1.5$$ But less than 2.04

If we want an equivalent F.S. as for $\gamma = 125$ psf B would need to be:

$$\frac{(20')(B)(105\text{ psf})\,(\tan(30))}{9.9\text{ kips}} = 2.04$$

$B = 16.7'$ or 0.84 H

Sliding Analysis



We find that the sliding analysis is very sensitive to the unit weight in both the resisting and driving zones and to the coefficient of friction utilized at the base of the wall.

Principal Modes of Failure - External

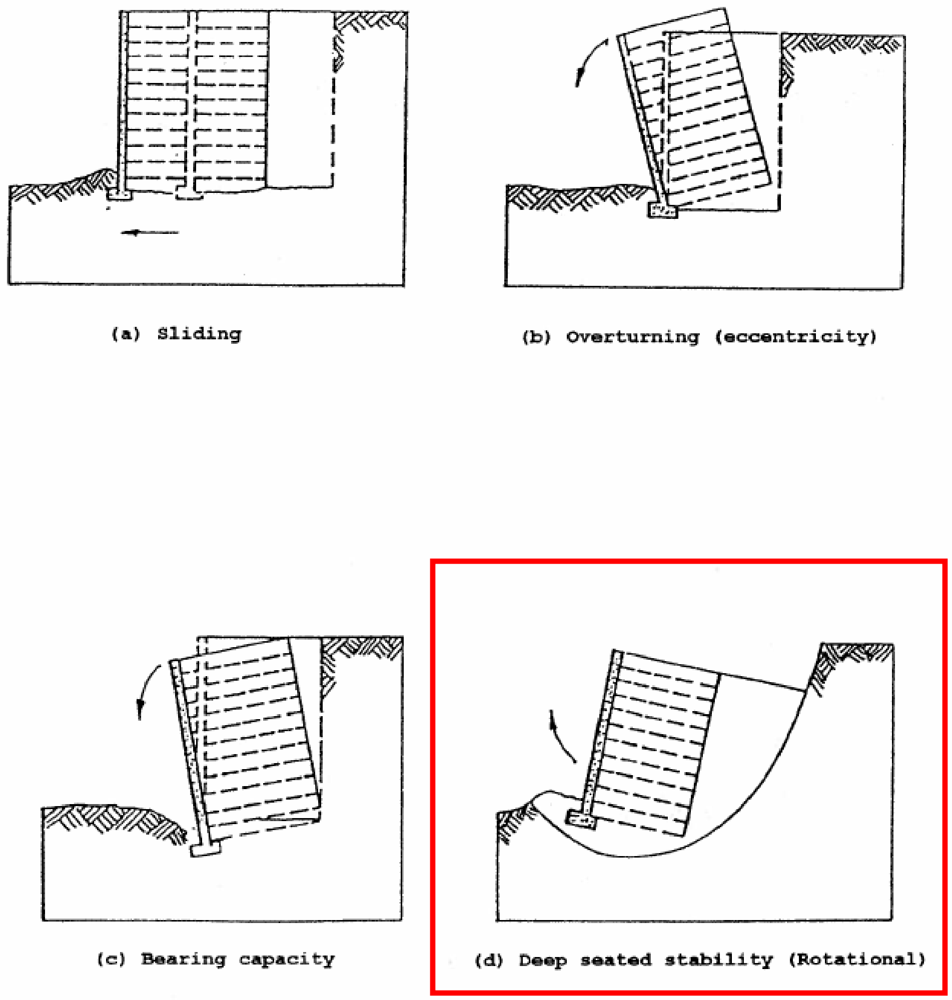


Figure 21. Potential external failure mechanisms for a MSE wall.

Soil Characteristics

- Stability of every wall must be evaluated
- Short-term and Long-term conditions (make sure that the soil strengths used in analysis are valid for the given soil profile).

Soil Characteristics

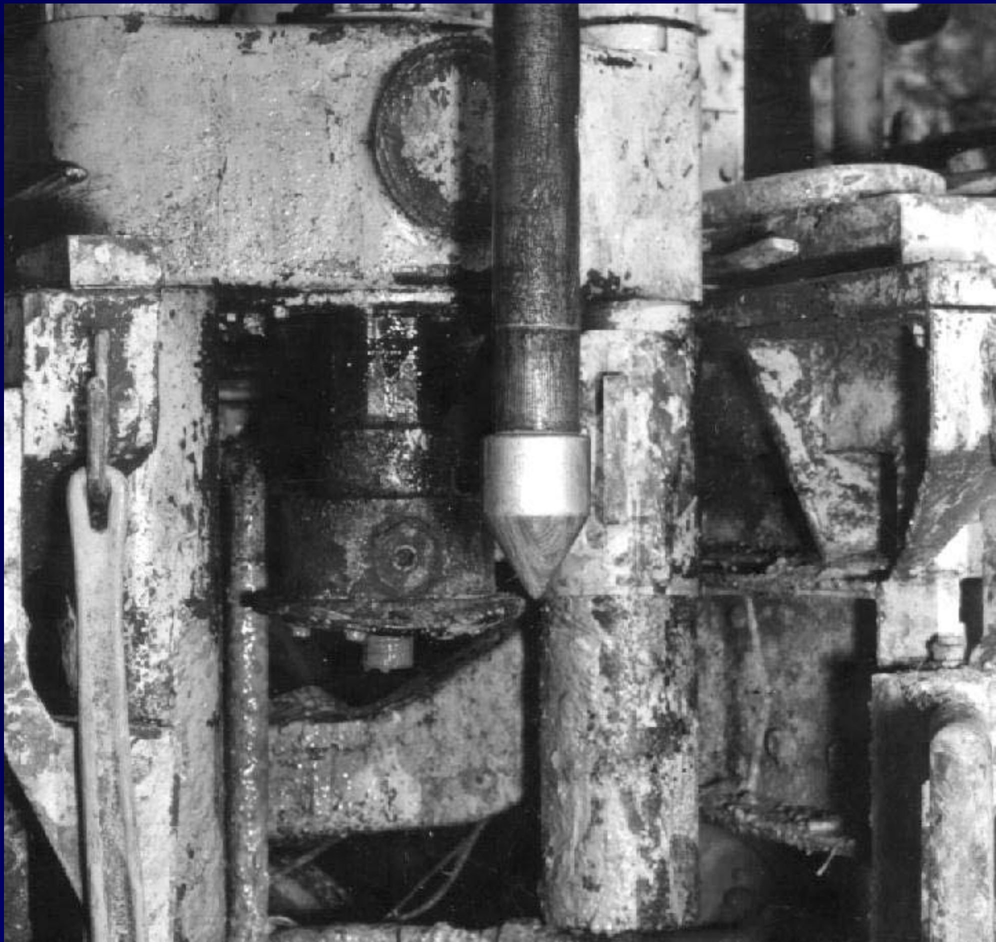
If the site investigation and geotechnical analysis results in design parameters that are different from those shown on the RW(MSE) standard, minimum factors of safety for the principle external modes of failure and a ground improvement strategy is not employed that would improve strength values to meet or exceed design parameters shown on the standard, *the design strengths must be communicated to the wall supplier. This can be accomplished by plan note or a modified standard reflecting lower strengths as applicable.*

DETERMINATION OF THE UNDRAINED SHEAR STRENGTH OF FINE GRAINED SOILS

Short Term Analysis

- TEXAS CONE PENETROMETER
- UNDRAINED TRIAXIAL TESTING
- IN-SITU VANE SHEAR TESTING
- DIRECT SHEAR TESTING

Texas Cone Penetrometer - TCP



DETERMINATION OF THE UNDRAINED SHEAR STRENGTH OF FINE GRAINED SOILS

- TEXAS CONE PENETROMETER
- Revised Correlation for blow counts less than 15 blows/12”, CTR Research Project 0-5824

Su= 300 + 60(blow count)

TRIAXIAL TESTING

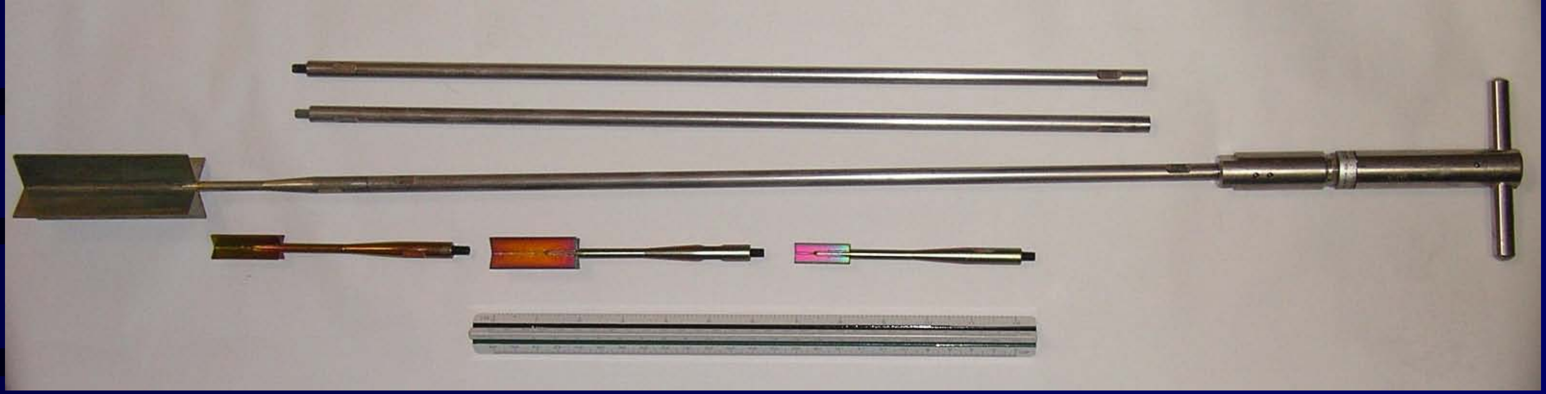
ADVANTAGES

- Long history of use in engineering practice
- Soil sample is retrieved
- Principle stresses are known
- Stresses can be varied to simulate the burial conditions in the field

DISADVANTAGES

- Test and Equipment are expensive
- Test is complicated
- Need a fair amount of soil for testing
- Results can vary due to:

  - End restraint conditions
  - Sample disturbance



IN-SITU VANE SHEAR TESTING

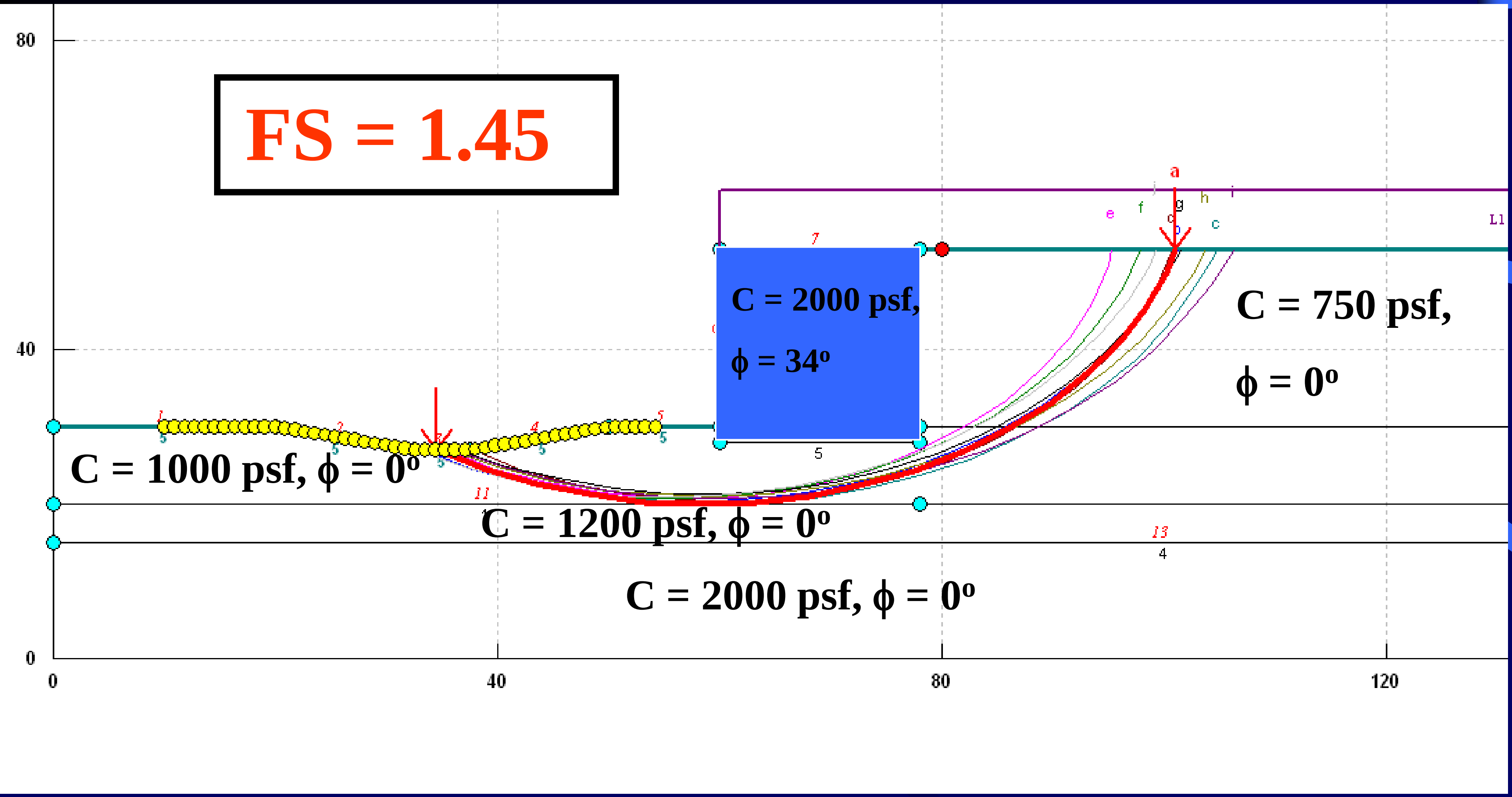
ADVANTAGES

- Rapid, simple, and inexpensive test
- Long history of use in engineering practice
- Reproducible results in homogeneous fine grained soils
- Minimal soil disturbance
- Yields the peak and residual undrained shear strength of fine grained soils

DISADVANTAGES

- No sample is recovered
- Limited to soft to medium stiff fine grained soils
- Results can be affected by roots, shells, gravel, sand seams, and lenses

SHORT TERM GLOBAL STABILITY ANAYLYS BASED ON APPROPRIATE SHEAR STRENGTH



DETERMINATION OF THE DRAINED SHEAR STRENGTH OF FINE GRAINED SOILS

Long Term Analysis

- Consolidated Undrained TRIAXIAL Test with Pore Pressure measurements.
- P.I. Correlation

CU TRIAXIAL TESTING

ADVANTAGES

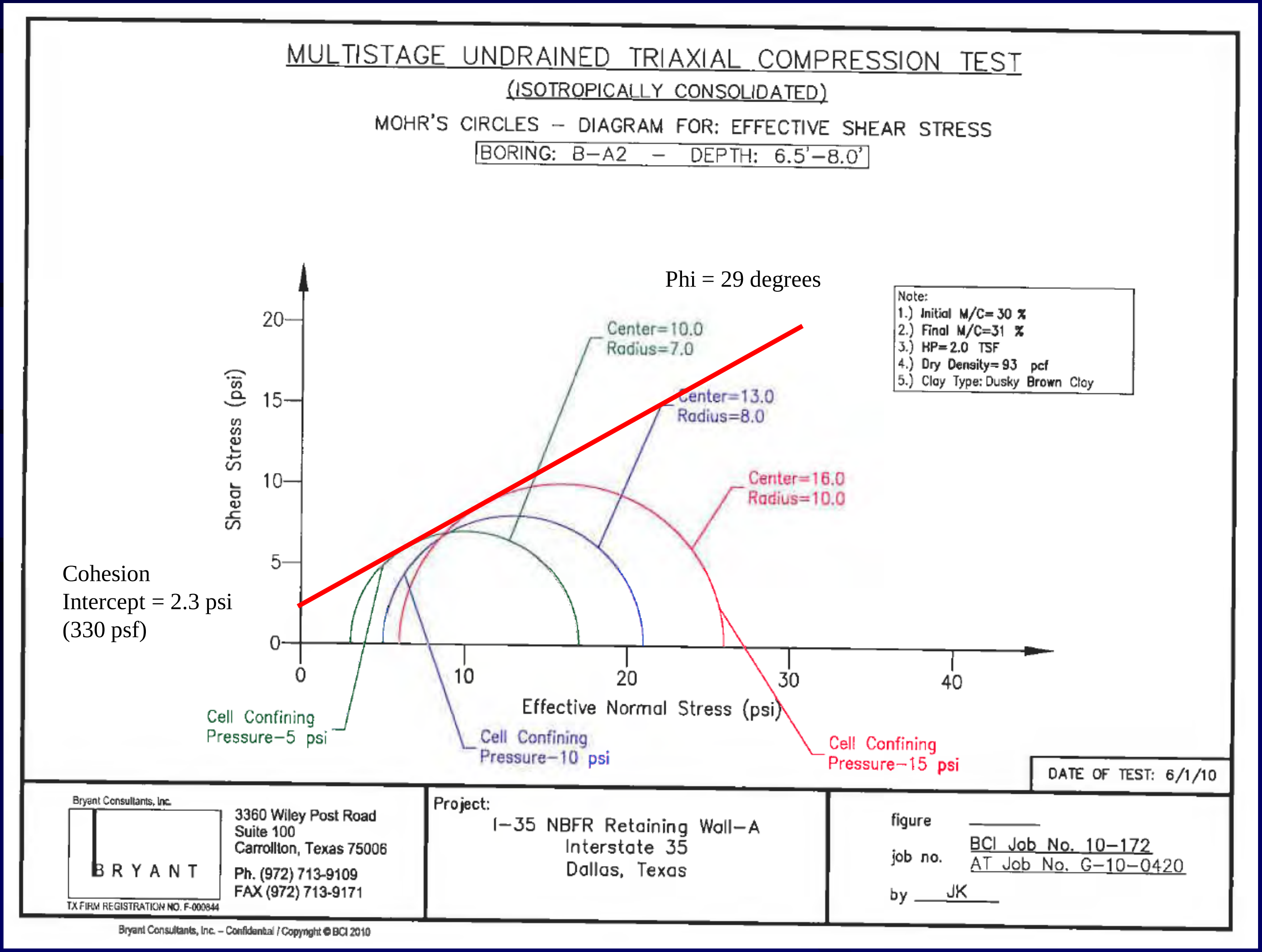
- Long history of use in engineering practice
- Soil sample is retrieved
- Principle stresses are known
- Stresses can be varied to simulate the burial conditions in the field

DISADVANTAGES

- Test and Equipment are expensive
- Test is complicated
- Testing Takes Time.
- Need a fair amount of soil for testing
- Results can vary due to:

  - End restraint conditions
  - Sample disturbance

CU Triaxial Test Results



P.I. Strength Correlation

- **<u>ADVANTAGES</u>**
- Quick
- History of use in engineering practice
- Various studies have contributed to the correlation charts.

<u>DISADVANTAGES</u>

- Correlation, does not take into account secondary structure of materials.
- Indirect measure of soil shear strength.
- Uncertainty in correlation.
- Cohesive component is unknown.

P.I. Strength Correlation

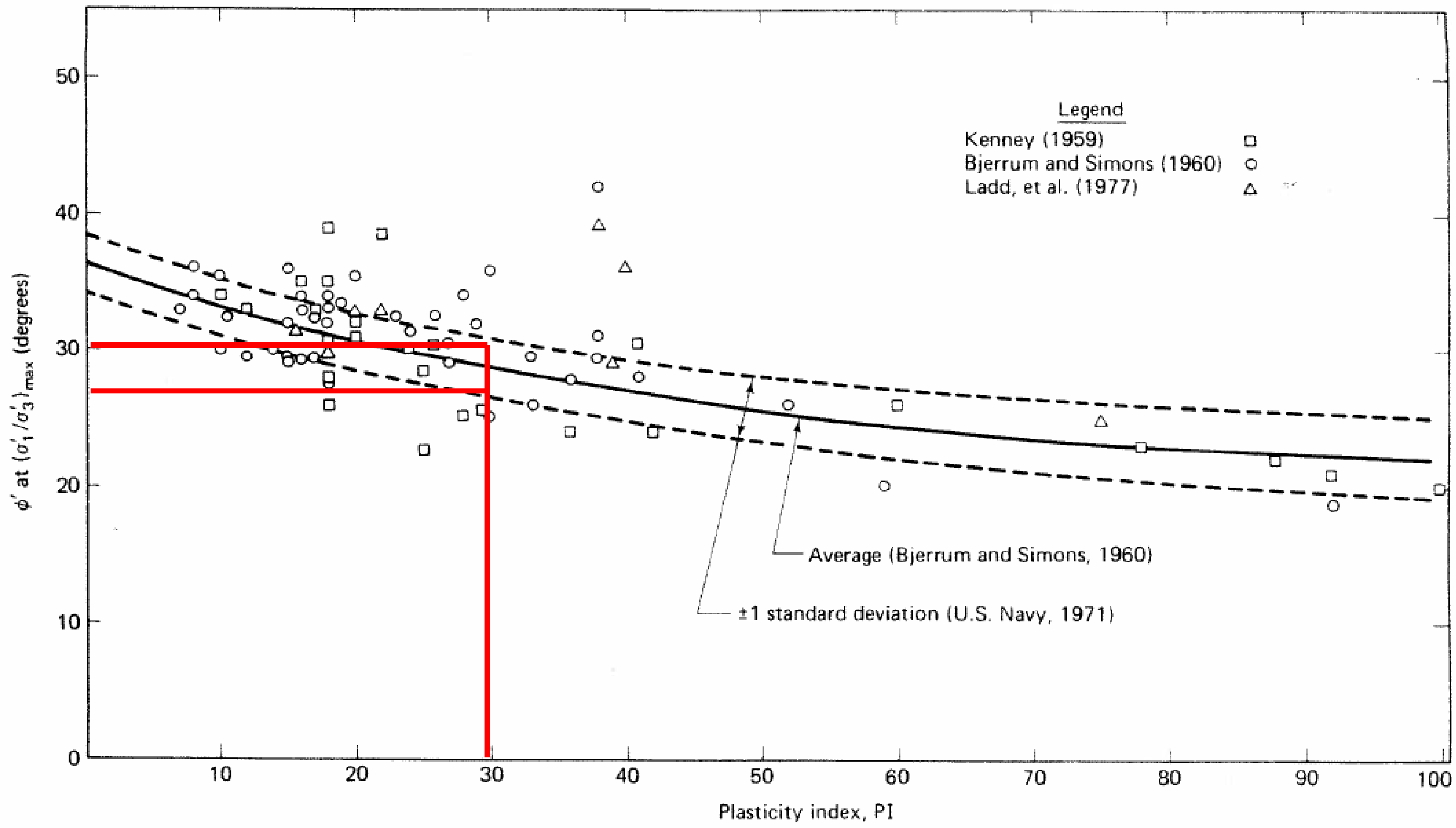
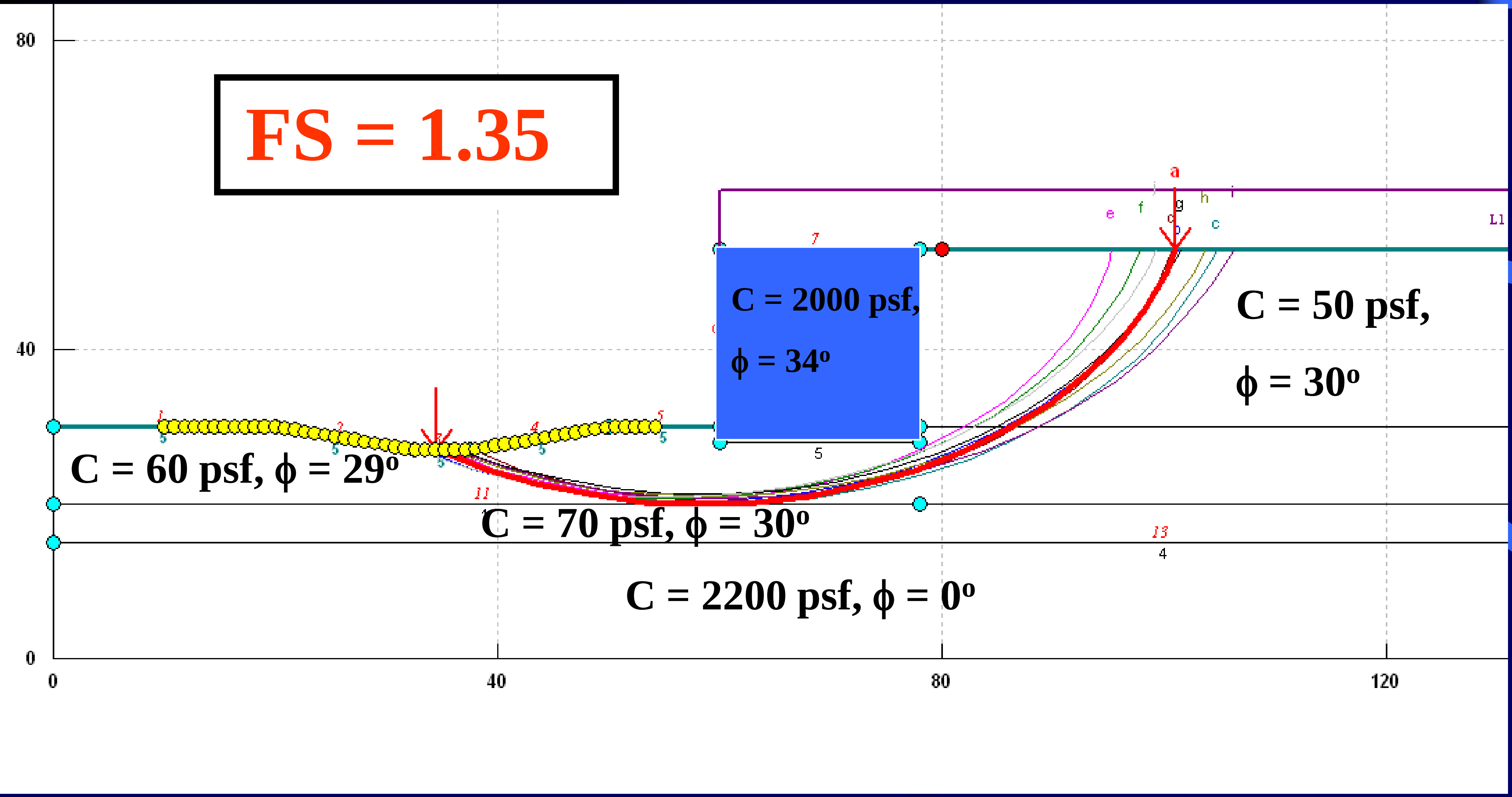


Fig. 11.27 Empirical correlation between φ' and PI from triaxial compression tests on normally consolidated undisturbed clays (after U.S. Navy, 1971, and Ladd, et al., 1977).

Long Term GLOBAL STABILITY ANAYLYS BASED ON APPROPRIATE SHEAR STRENGTH



Principal Modes of Failure - External

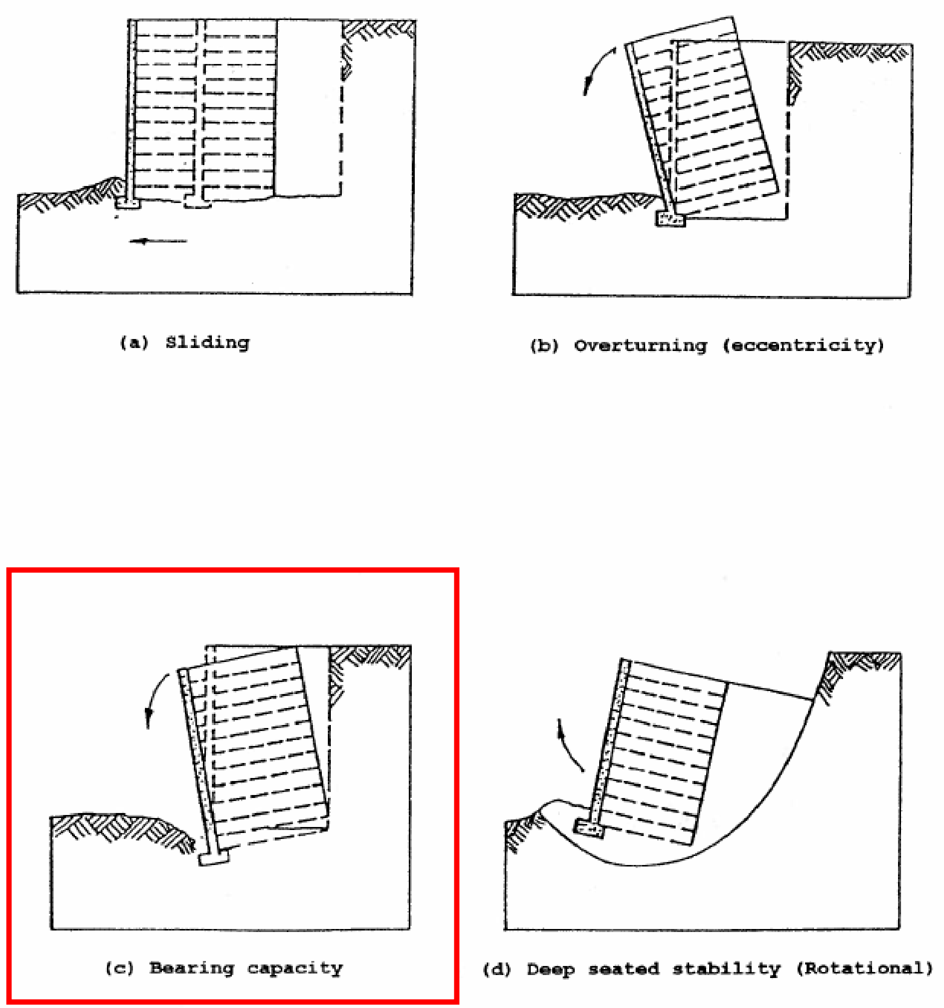
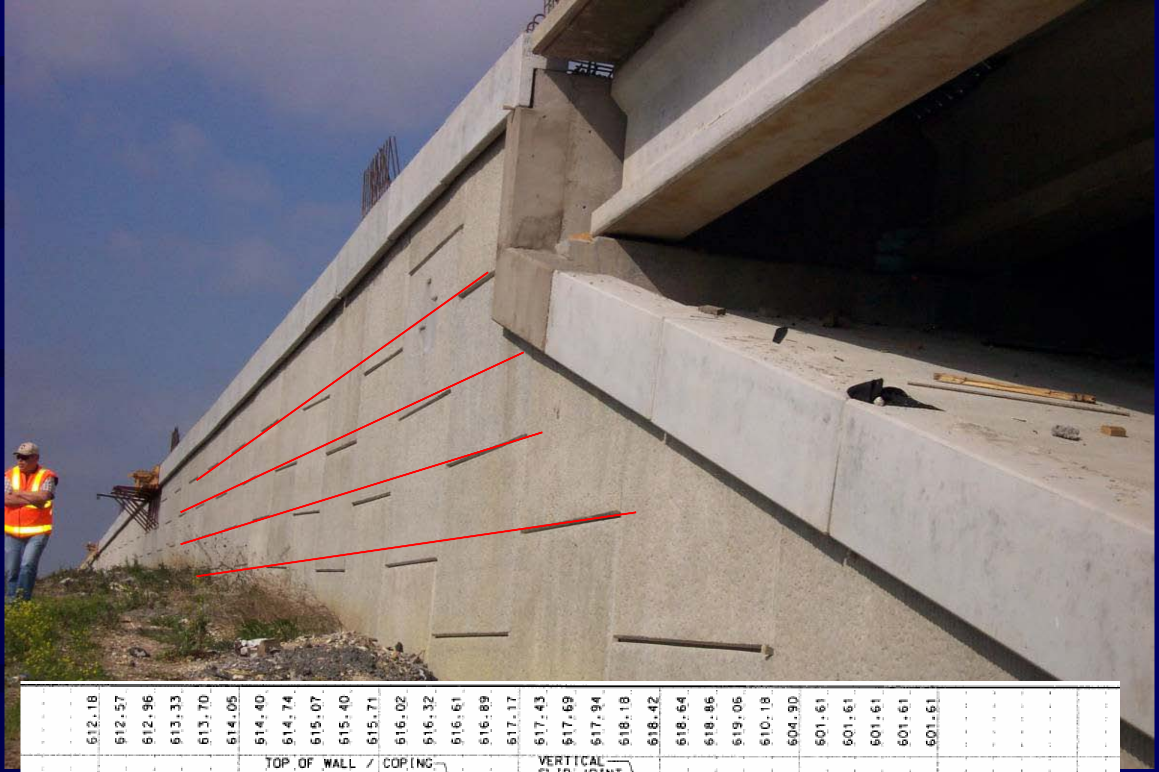


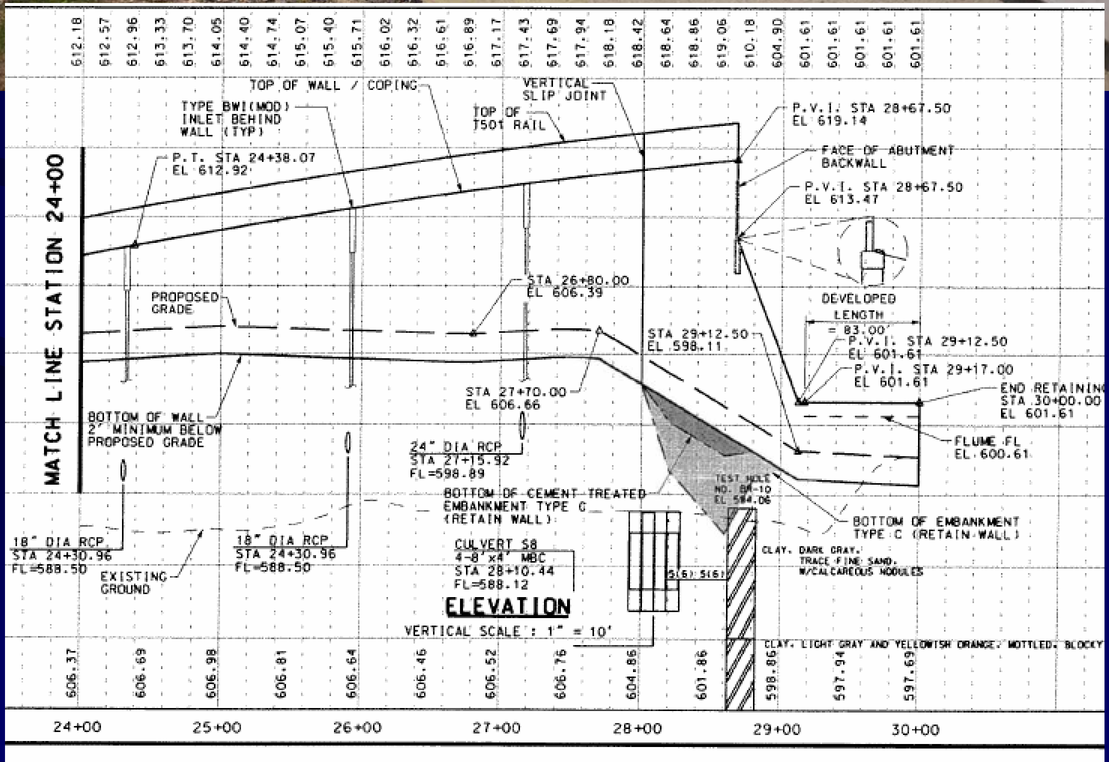
Figure 21. Potential external failure mechanisms for a MSE wall.

OTHER CONSIDERATIONS

POOR PREPARATION
OF RETAINING WALL
FOUNDATION SOILS

MSE Wall W/Fill and Ground Improvement

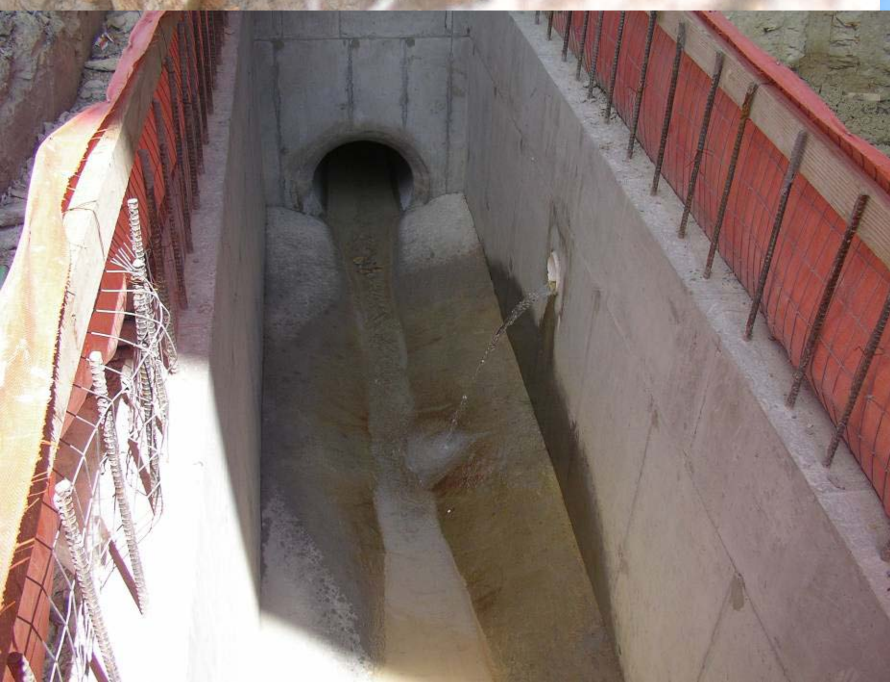




Foundation Settlement

Ground Water Table

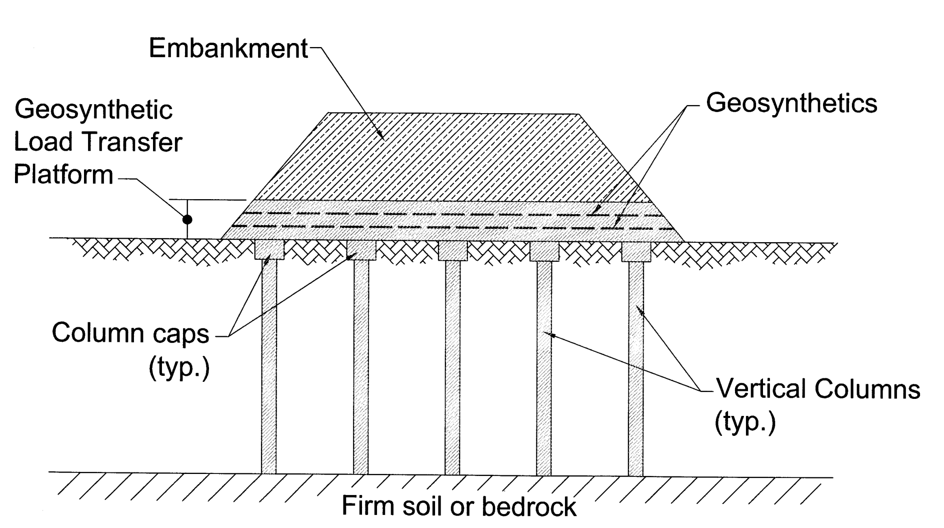
Wall Drainage



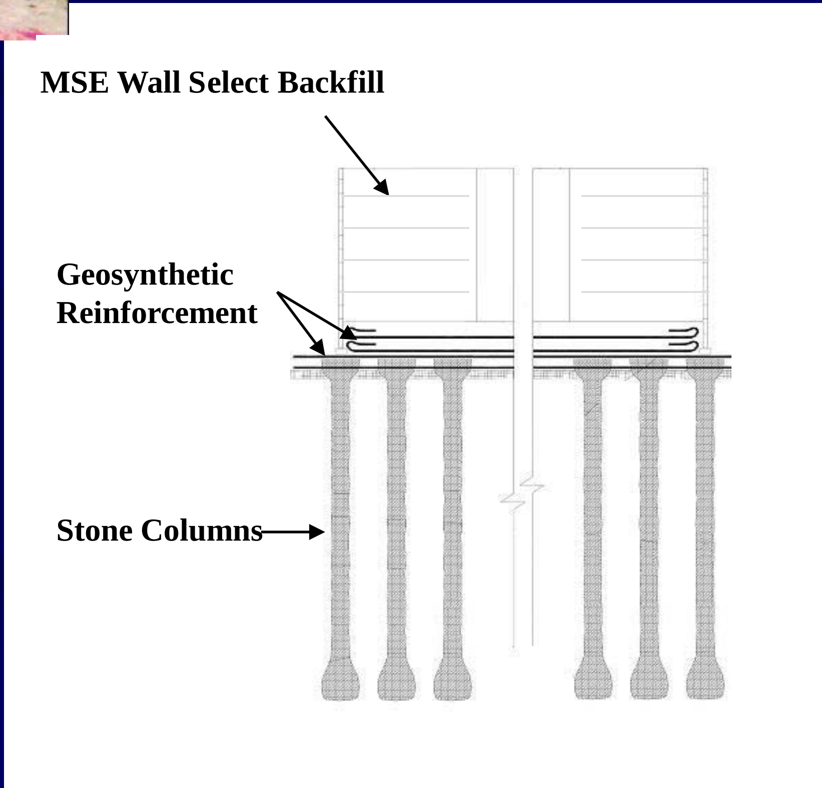
Special Design Considerations

- Ground Improvement
  - Remove and Replace
  - Stone Columns
  - Rammed Aggregate Piers

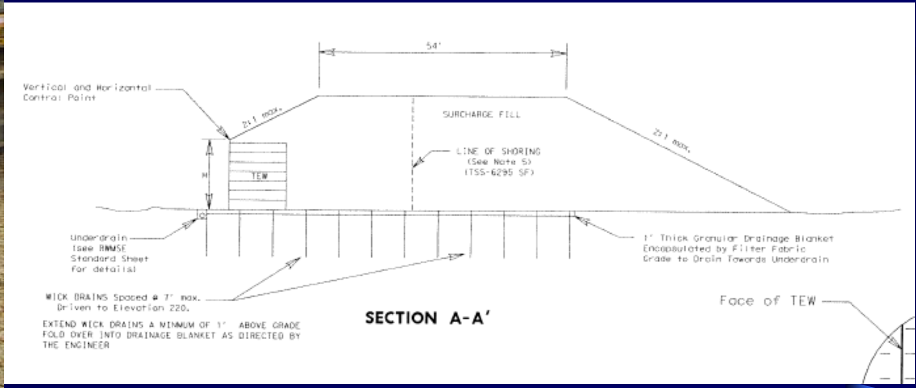
Pile Supported Embankment

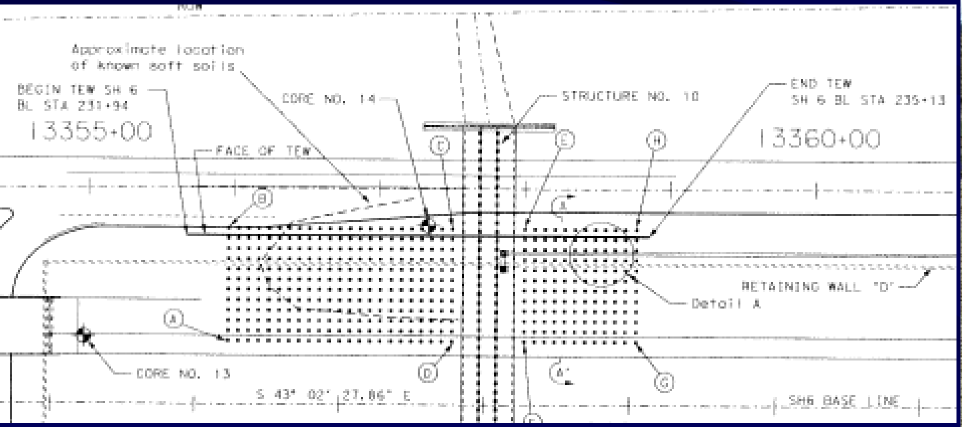


Stone Columns/Geopiers



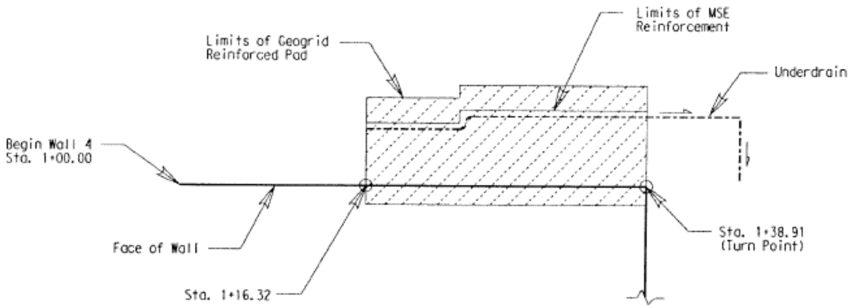
Remove and Replace/Wick Drains



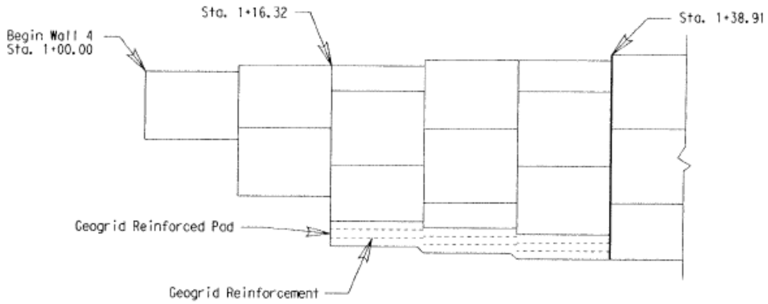


Remove and Replace – Reinforced Pad

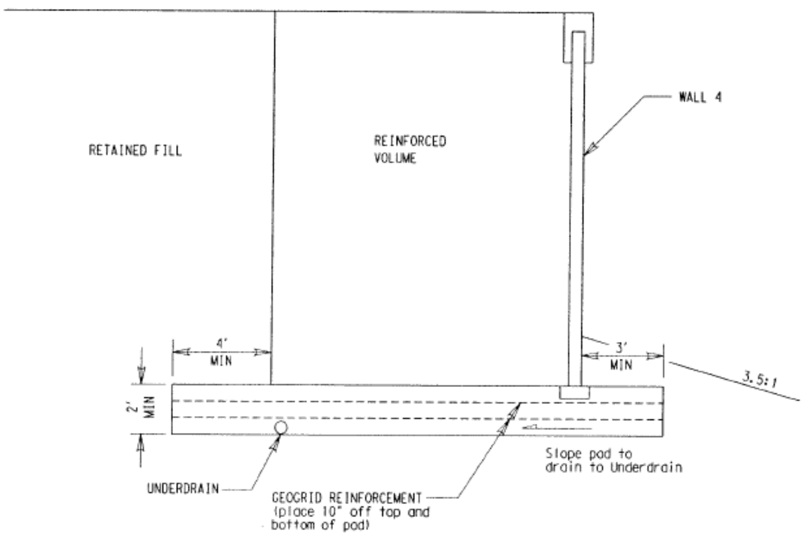
ESTIMATED QUANTITIES		
DESCRIPTIONS		QUANTITIES
SELECT FILL (Stabilized Pad)	CY	29
GEOGRID	SY	43



PARTIAL PLAN - WALL 4



PARTIAL ELEVATION - WALL 4



STABILIZED PAD TYPICAL SECTION

(Wall 4 Sta. 1+16.32 to Sta. 1+38.91)

GENERAL NOTES

Stabilized Pad to be constructed under Wall 4 between Sta 1+16.32 to Sta. 1+38.91. Pad to be composed of select fill used for reinforced volume of the MSE wall and reinforced with two levels of geogrid reinforcement. Geogrid to be Mirafi - Miragrid 3XT or equivalent and have a minimum LTDS of 1300 lbs/ft.

Geogrid to be placed 10" off the top and bottom of stabilized pad.

Underdrain pipe to be place to drain section of MSE wall treated with stabilized pad.

Run underdrain at back of strap of retaining wall from Sta. 1+00 to (1+38.91)+15'. The underdrain is then to run down slope for 10' min.

REV.	C.O. #	DESCRIPTIONS	DATE	DN
△				
△				

TEXAS DEPARTMENT OF TRANSPORTATION

WALL 4 STABILIZED PAD

CONCLUSIONS

- TxDOT has designed and constructed numerous MSE retaining walls.
- In spite of the increased usage, TxDOT has had relatively few retaining wall failures.
- The design and planning phase of retaining walls is critical and must address the actual site conditions, including soil and loading, that the wall will be subjected to.
- If values in the analysis of the wall (i.e. friction angle for both the retained and foundation soils) are less than that shown on the RW(MSE) standard and do not result in a ground improvement that would positively impact these values, the designer of record should include the soil strength information in the plan set for use by the wall supplier.

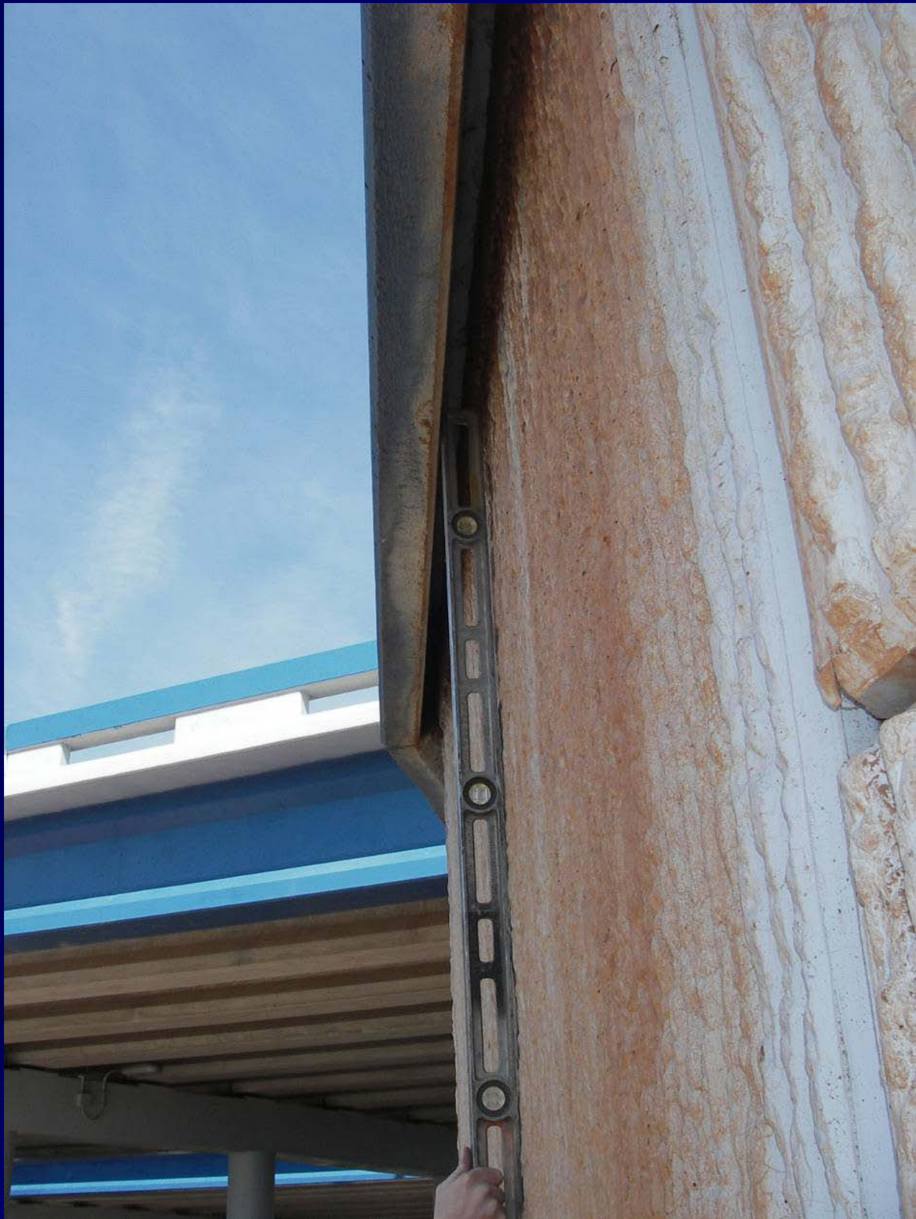
QUESTIONS?

Ground Conditions

- Soil Shear Strength
  - Short Term, C and phi
  - Long Term, C’ and phi’
- Ground Water Table
- Necessary Fill
- Necessary Cut

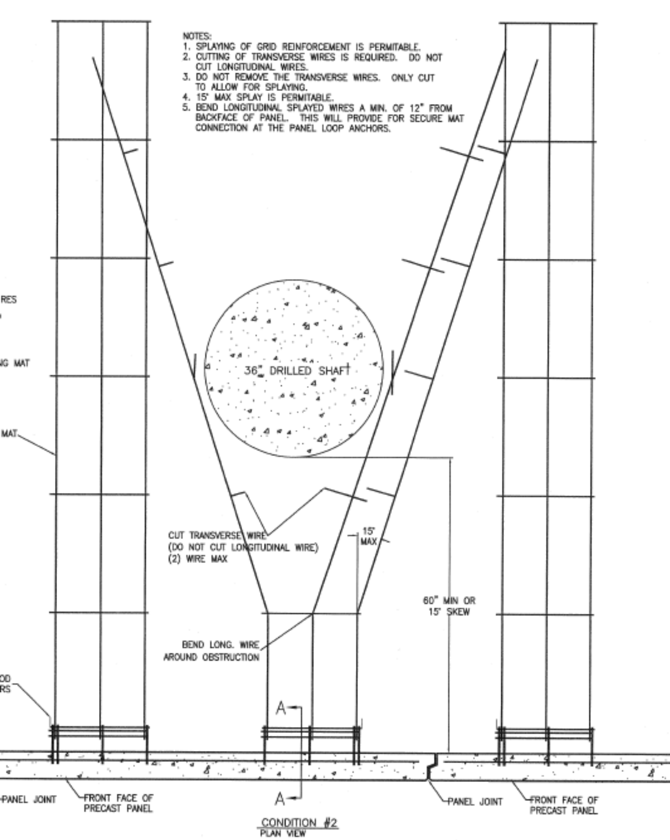
MSE Principal Modes of Failure

LOSS OF MSE BACKFILL

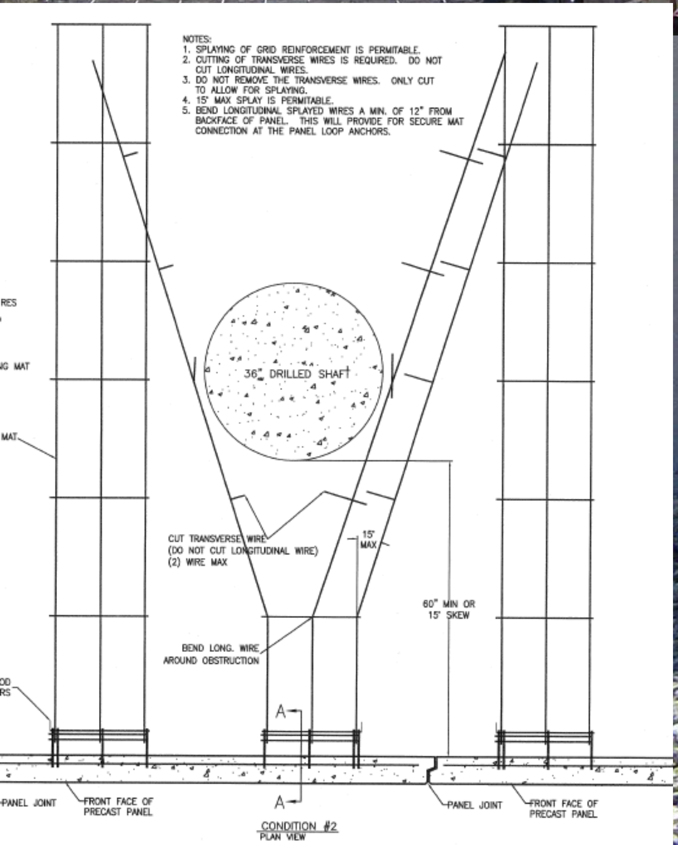


LOSS OF MSE BACKFILL

Obstructions



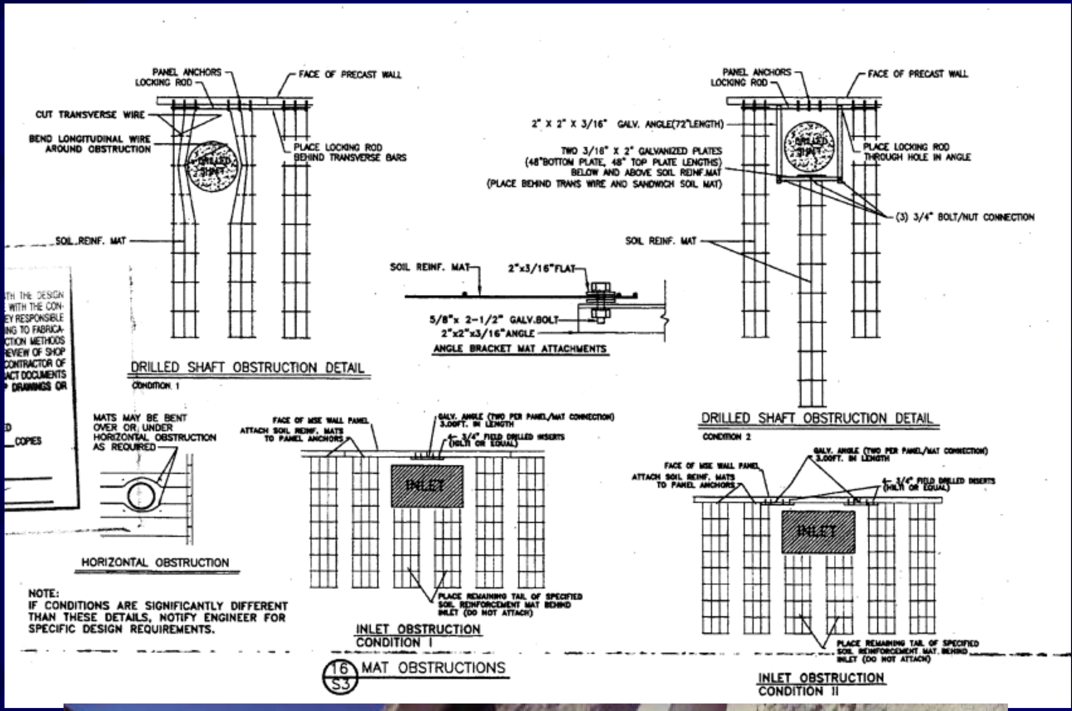
Obstructions



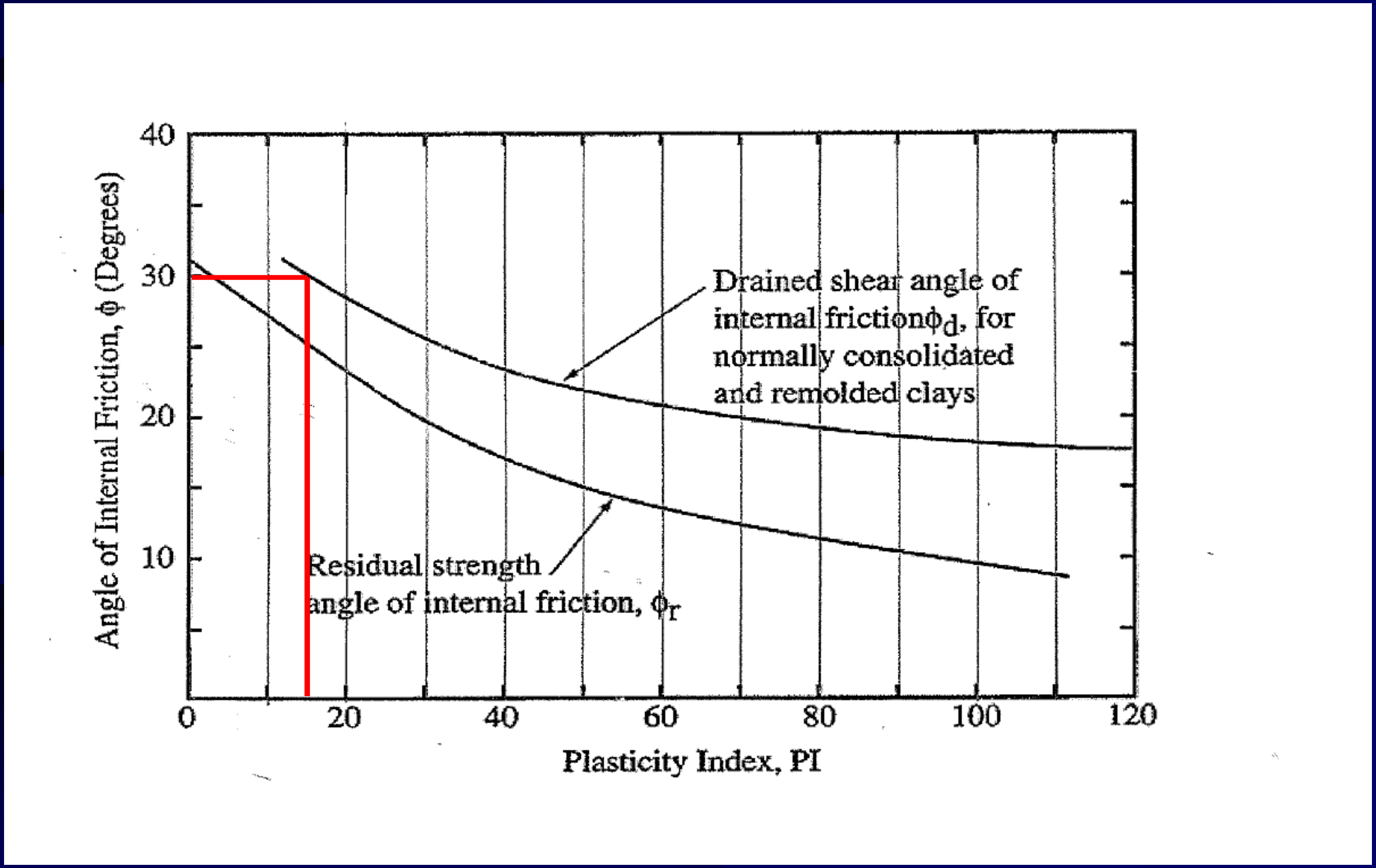

Incomplete connection with locking rod.
Soil reinforcing mat is rotated by wedging to the back of panel. This prevents bearing of the grid to the locking rod allowing potential of movement on the right side of the panel.
Photo 1
2008 2

Obstructions

Omitted Reinforcement



P.I. Strength Correlation



Design Considerations
vs
Special Design Considerations

TEW WALL Dissimilar Earth Reinforcement

TEW WALL