

1.364 ADVANCED GEOTECHNICAL ENGINEERING
HOMEWORK No. 5

Due: Friday December 12

1. This question concerns the stability of an open slope cutting that will be used to provide construction access for a 13.2m deep excavation in Boston. The site is level with ground surface at El. +34.2m with a soil profile shown in Figure 1a. The groundwater table is at El. +31.5m and pore pressures are assumed to be hydrostatic. Table 1 summarizes the unit weight and shear strength properties of the soils at the site, while Figure 1b provides additional field vane data from which the undrained shear strength of the Boston Blue Clay layers can be estimated. Using the soil properties provided and the slope stability program Autoslope (on the CEE net – S:\analysis\autoslope), find the maximum slope inclination angle, i , which will ensure a factor of safety, $FS = 1.5$ for short term (undrained) stability. For your selected slope angle, what is the factor of safety for long term drained stability?

In the first calculation you should assume that the undrained shear strength of the cohesive fill, silt and BBC layers are controlled by the in situ effective stress (σ'_{v0}). In the second calculation, the water table will be maintained below the excavated grade within the excavation itself. [You will need to sketch a flow net in order to estimate the pore pressures within the slope.]

You should include full details of the assumptions used in your analyses, together with plots showing the location of the critical slope failure mechanisms.

2. A new subway extension in Berlin involves the construction of 1.2m thick concrete diaphragm walls forming the side walls of the station with a 1.5m thick base slab connecting the walls (Figure 2a). The walls are to be tied back with permanent ground anchors. The subsoil profile at the site consists of thick layers of Berlin sand. The soffit of the base slab is 22m below the existing ground surface. As the water table is only 1.5m below the ground surface, the structure has to be tied down against uplift water pressures acting against the base slab. Due to the proximity of the excavation to sensitive structures around the site, the excavation cannot be dewatered until the base slab has been cast to seal the water inflow. As a result, the following excavation sequence has to be adopted:-

Stage 1. Install retaining walls from existing ground surface

Stage 2. Excavate to temporary platform for installation of ground anchor (2.5m below ground surface)

Stage 3. Excavate to soffit of base slab at 22m depth

Stage 4. Cast base slab underwater and seal joints with retaining walls by grouting

Stage 5. Pump out water in excavation to lower the water level to below the top of the base slab.

Stage 6. Install tie-down piles and secure piles to base slab

Stage 7. Terminate pumping

Results of triaxial tests run on Berlin sand at different relative densities (D_r) and mean effective stresses (σ_m) are given in Figure 2b.

- a. Find the embedment depth of the retaining wall required for stability of the excavation.
- b. Specify the spacing for the anchor and determine the prestress force based on the most critical condition at the end of excavation (no drawdown of water inside excavation).
- c. Design the inclination and length of the anchor based on a nominal bore diameter of 150mm, indicating clearly the locations of the free and fixed lengths of the anchor (assuming no restriction on anchor lengths outside the site boundary). The geotechnical factor of safety for a permanent ground anchor is 2.0.
- d. The base slab is to be anchored by 200mm diameter concrete friction piles. Calculate the length and spacing required, assuming a geotechnical factor of safety of 1.5 on the ultimate shaft resistance is adequate.

3. A typical section of the MBTA transitway project in Boston is supported by 3 ft thick concrete diaphragm walls with five levels of cross-lot bracing, Fig. 3a. The site has level ground surface (El. 112ft) and the toe of the wall extends to an elevation of +24 ft. The allowable structural moment capacity of the diaphragm wall is 265 kips-ft/lin. ft. The struts consist of steel pipe sections with an outer diameter of 30ins and wall thickness of 0.75ins, located at a horizontal spacing of 22 ft. Excavation is carried out from the existing ground surface at +112 ft elevation. The sequence of excavation and strutting is set out in Figure 3a. The soil properties at the site are summarized in Table 3. Figure 3b gives the existing in situ soil stresses and pore

water pressures in the ground. (For the purpose of this exercise, use the revised profile for σ'_{ho} in Figure 3b.).

- a. Using empirical apparent earth pressure diagrams methods, recommend a design lateral earth pressure envelope (this should include the effects of a 600psf construction surcharge load applied at the ground surface and extending up to 20ft behind the wall).
- b. For this assumed set of apparent earth pressures, what are the expected loads in each level of strut.
- c. Check the basal stability of the excavation using the methods discussed in the Course Notes
- d. Determine the likely ground settlement profile induced by the excavation using the method of Clough et al (1989)

Soil Type	Unit Weight (kN/m ³)	Undrained Shear Strength (kPa)	Drained Strength Parameters	
			c' (kPa)	φ'
Granular Fill	18.9	-*	0	30 ⁰
Cohesive Fill	18.0	0.35σ' _{v0}	0	30 ⁰
Organic Silt	17.3	0.25σ' _{v0}	0	35 ⁰
BBC	18.5	see Fig. 1c	0	33 ⁰
Glacial Till	23.1	-	0	43 ⁰

* Fully drained

Assume hydraulic conductivity of cohesive fill, organic silt and BBC, $k = 5 \times 10^{-7}$ cm/sec

Table 1. Soil Properties for Stability Analyses

Soil Type	Elevation (ft)	OCR	S _u (ksf)	φ' (degree)	γ _t (pcf)
Misc. Fill	112 to 106	-	-	30	120
Cohesive Fill	106 to 99	-	0.15	-	115
	99 to 91		0.26		
	91 to 84		0.36		
Silty Sand	84 to 72	-	-	35	120
Upper BBC	72 to 64	3.00	SHANSEP S = 0.2 m = 0.77	-	115
	64 to 56	2.52			
	56 to 48	2.14			
	48 to 40	1.79			
	40 to 32	1.46			
	32 to 24	1.25			
Lower BBC	24 to 16	1.00	SHANSEP S = 0.18 m = 0.66	-	115
	16 to 8	1.00			
	8 to 0	1.00			
	0 to -8	1.00			
	-8 to -16	1.00			
	-16 to -25	1.00			

Table 3. Soil profile and properties for MBTA excavation

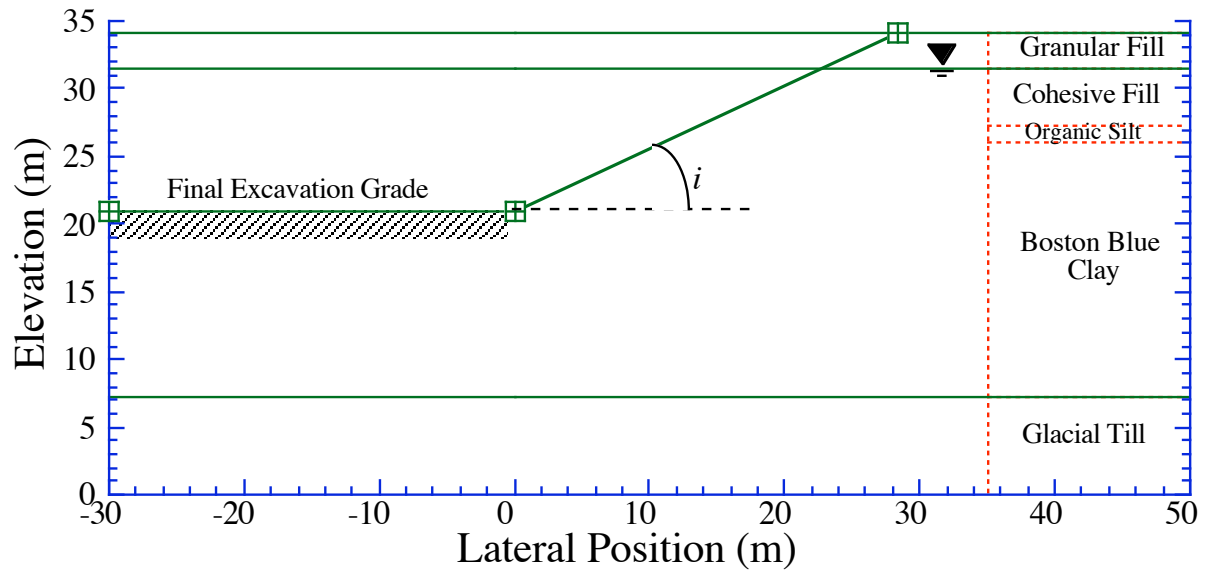


Figure 1a. Slope excavation

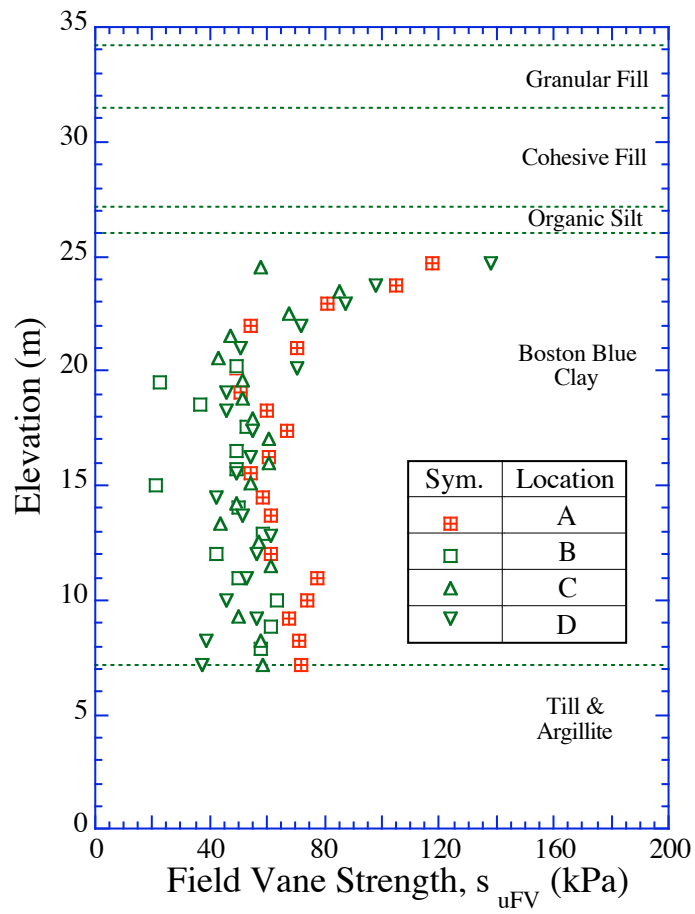


Figure 1b. Undrained Shear Strength Data for Boston Blue Clay

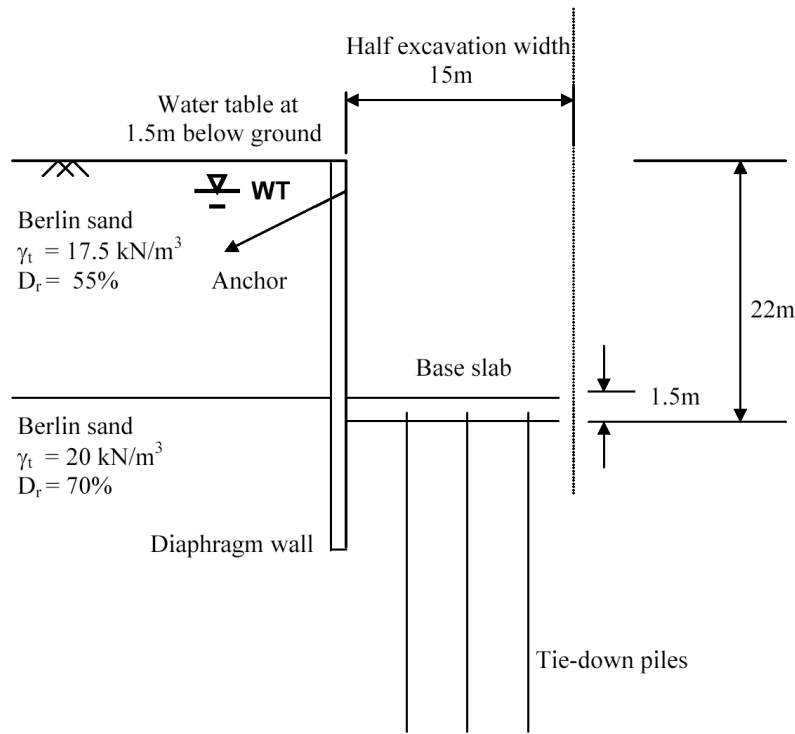


Figure 2a. Schematic of anchored retaining wall and tied-down base slab scheme

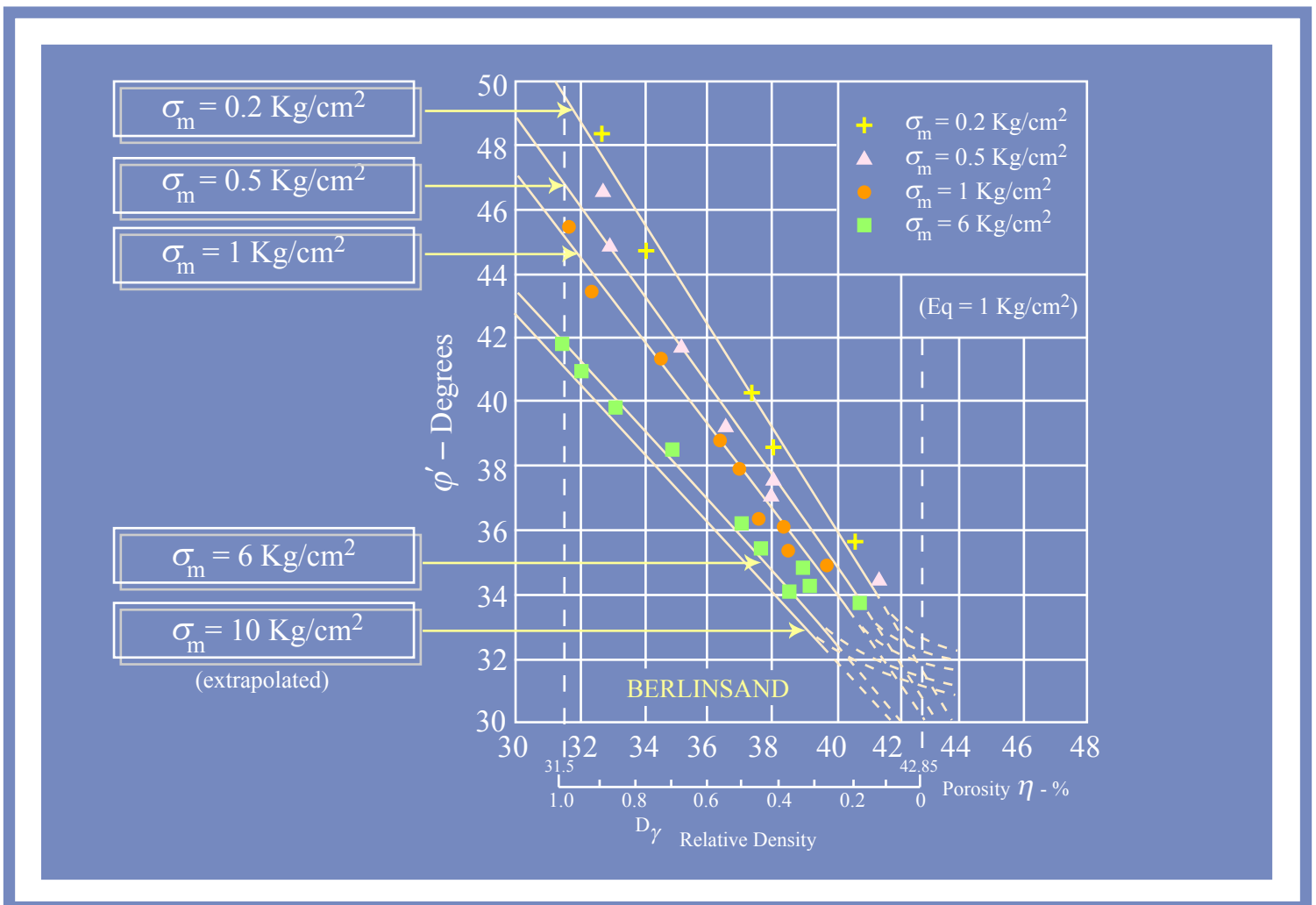


Figure 2b. Friction angle of Berlin sand obtained from triaxial tests

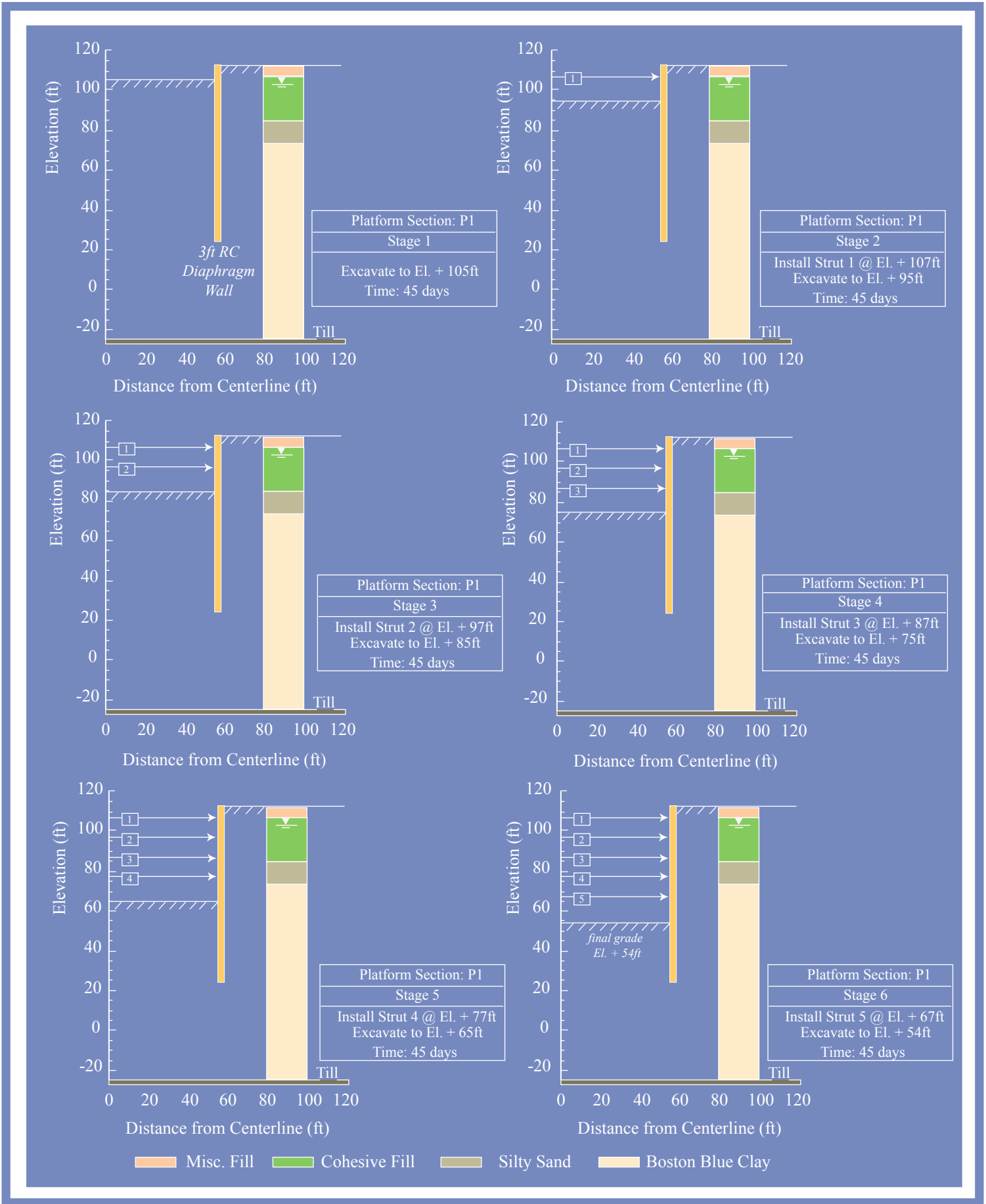


Figure 3a. Excavation and strutting sequence, MBTA Transitway , South Boston

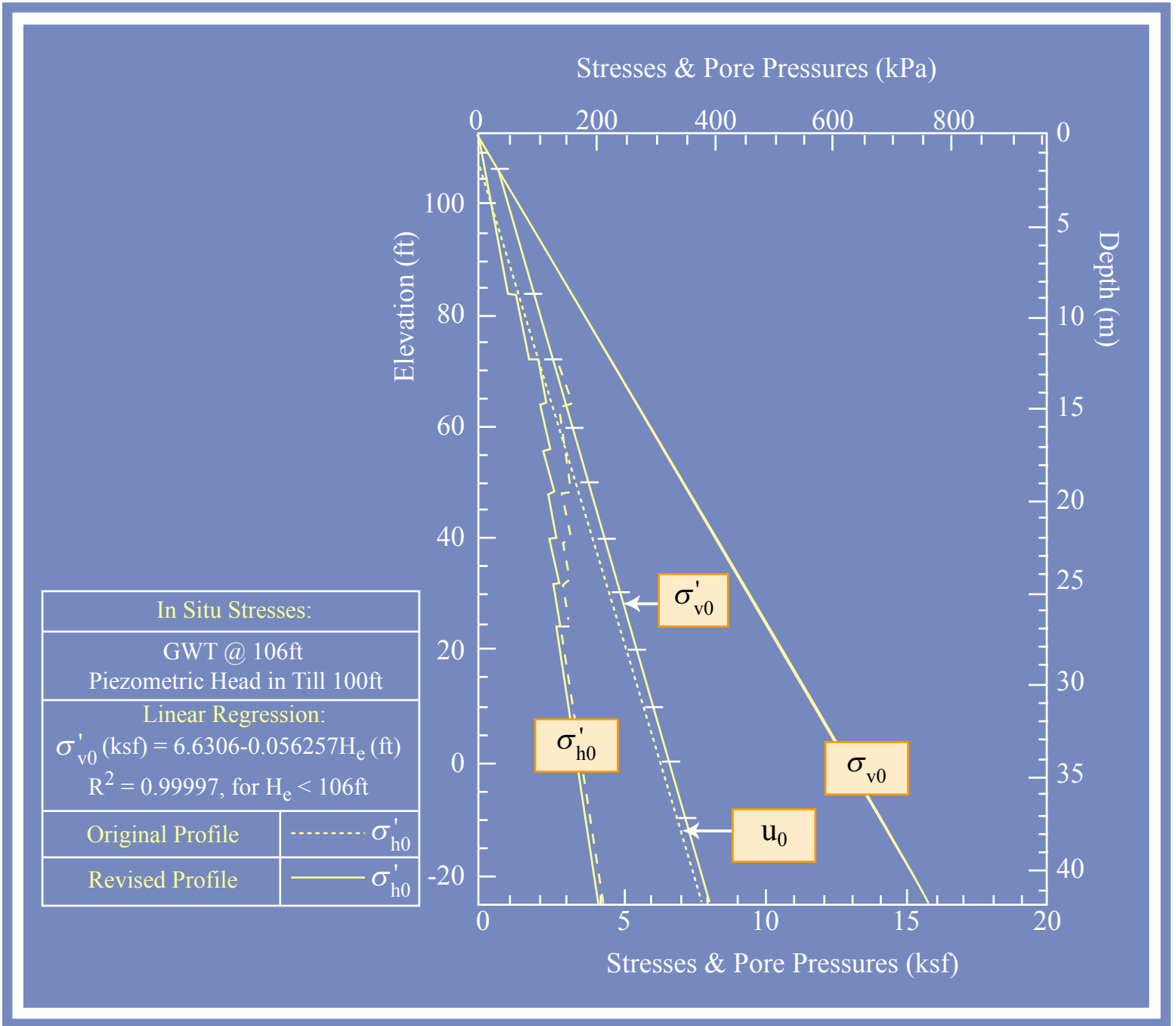


Figure 3b. In situ stresses and pore water pressures