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# 14.528 Drilled Deep Foundations
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# Homework No. 1

## Economics of Deep Foundations

### GENERAL
The new Green Line Extension (GLX) project will extend the rail transportation from Cambridge to Somerville and Medford. Most of the track will be carried over a viaduct supported by piers. At the location of two piers, alternatives of deep foundations were evaluated leading to a comparison between 16in diameter, 0.5in wall thickness driven pipe piles to 7ft diameter drilled shafts with 6ft diameter rock socket, a single element under each column location.

### PIERS DESCRIPTION
Pier A and Pier B of the viaduct are situated over 300 feet apart. The proposed design for Pier A includes a 59-foot-wide pier cap supported on three columns, while the proposed design for Pier B includes a 36-foot-wide pier cap supported on two columns. For both piers, the center-to-center spacing between the 6.25-foot-diamter columns is 24 feet. The top of Pier A will be approximately at El. 42 and the final grade will be approximately El. 19.00. The top of Pier B will be approximately El. 45, while the final grade will be approximately at El. 20.

### SUBSURFACE CONDITIONS
The stratigraphy beneath Pier A consists generally of manmade fill underlain by naturally-deposited organic silt, clay, glacial deposits (possible till), highly weathered rock and rock. The depth to top of highly weathered rock is approximately 80 feet below ground surface (bgs), while the depth to top of rock is approximately 140 feet bgs. The stratigraphy beneath Pier B consists generally of manmade fill underlain by naturally-deposited sand, clay, glacial deposits (possible outwash), highly weathered rock and rock. The depth to the top of highly weathered rock is approximately 58 feet bgs, while the depth to top of rock is approximately 70 feet bgs. Note that top of rock in this context is considered to be consistent with the top of rock coring, regardless of rock quality designation (RQD). Detailed descriptions of the subsurface conditions at each pier location are provided in Tables 1 and 2 below. GWE is at approximately 18ft bgs for Pier A and 15ft bgs at Pier B. Ground elevation approximately coincides with the aforementioned final grade at the piers' location.

**Table 1. Stratigraphy and Soil Properties – Pier A**

| Stratum | Top (ft bgs) | Bottom (ft bgs) | Thickness (ft) | $(N_1)_{60}$ (bpf) | $D_r$ (%) | $\gamma_t$ (pcf) | $\phi'$ (deg.) | $s_u$ (psf) |
|---|---|---|---|---|---|---|---|---|
| Fill | 0 | 28 | 28 | 20 | 50 | 120 | 33 | |
| Organic silt | 28 | 38 | 10 | | | 110 | | 500 |
| Clay | 38 | 66 | 28 | | | 118 | | 1,300 |
| Glacial deposits | 66 | 80 | 14 | 100 | 80 | 135 | 36 | |
| Weathered rock | 80 | 140 | 60 | | | 140 | 38 | |
| Rock | 140 | | | | | | | |

**Table 2. Stratigraphy and Soil Properties – Pier B**

| Stratum | Top (ft bgs) | Bottom (ft bgs) | Thickness (ft) | $(N_1)_{60}$ (bpf) | Dr (%) | $\gamma_t$ (pcf) | $\phi'$ (deg.) | $s_u$ (psf) |
|---|---|---|---|---|---|---|---|---|
| Fill | 0 | 24 | 24 | 20 | 50 | 120 | 33 | |
| Sand | 24 | 36 | 12 | 24 | 55 | 122 | 34 | |
| Clay | 36 | 54 | 18 | | | 118 | | 2,100 |
| Glacial deposits | 54 | 58 | 4 | 20 | 55 | 125 | 34 | |
| Weathered rock | 58 | 70 | 12 | | | 140 | 38 | |
| Rock | 70 | - | - | | | | | |

## DEEP FOUNDATIONS DESIGN ALTERNATIVES

1. Single Pile Cap Design for Each Pier Location
   Figures 1 and 2 present the layout of piles and pile caps in the single cap design for Piers A and B, respectively. Each cap is 4ft thick and the top of the cap is 4ft below ground surface. The piles supporting Pier A are 87ft long and those supporting Pier B are 65ft long.

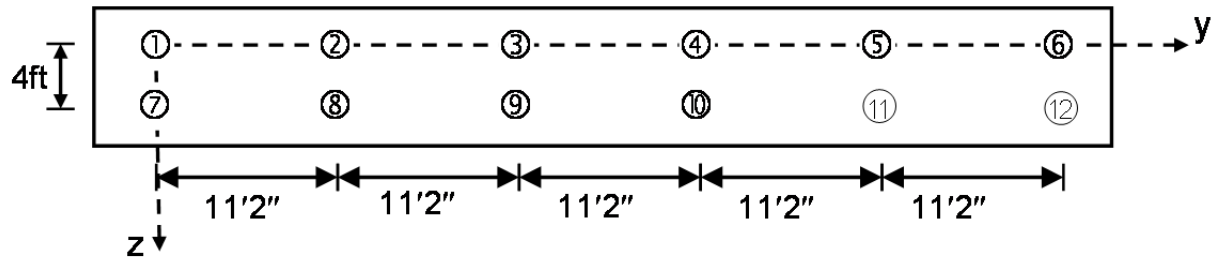


**Figure 1.** Schematic of pile group configuration for a single pile cap design at Pier A (59 ft × 7 ft pile cap)

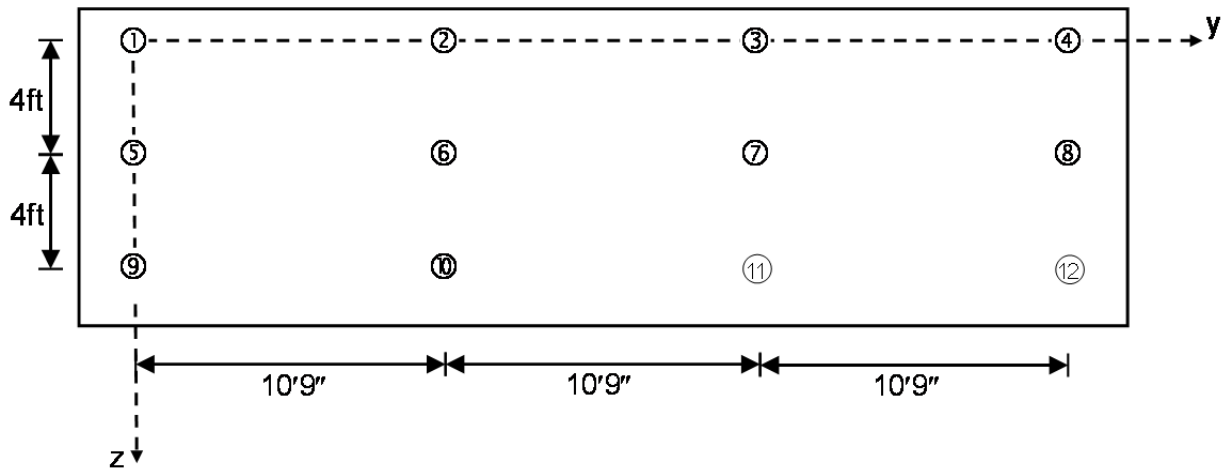


**Figure 2.** Schematic of pile group configuration for a single pile cap design at Pier B (35 ft × 11 ft pile cap)

2. Drilled Shaft Design
   Table 3 presents the drilled shaft design for Piers A and B where each column is supported by a single drilled shaft.

**Table 3. Drilled Shaft Design Alternative for Piers A and B**

| Pier Number | Column | Total Length of Drilled Shaft (ft) | Length of Shaft above Weathered Rock (ft) | Length in Rock (ft) |
|---|---|---|---|---|
| Pier A | North Column | 126 | 80 | 46 |
| | Center Column | 138 | 80 | 58 |
| | South Column | 130 | 80 | 50 |
| Pier B | North Column | 106 | 58 | 48 |
| | South Column | 104 | 58 | 46 |

## COST EVALUATION

You are requested to carry out a cost comparison between the two presented deep foundation alternatives. For that purpose, use the MassDOT website, Weighted Bid Prices http://www.mhd.state.ma.us/cpe/WeightedAverageCriteria.aspx For additional cost values you can use Means cost data, www.get-a-quote.net, download a software sample using http://craftsman-book.com/downloads/index.php?page=trial, or use typical known values. You may contact a contractor. Make sure to specify the source of your information. In conducting your analysis you should consider at least the following cost items (you may choose additional items or modification of those listed; specify).

For the drilled shaft construction consider the following costs:

1. DS excavation (soil/rock) – drilling
2. Permanent casing – assume casing of ¾ ″ wall thickness from surface to top of rock
3. Soil disposal
4. Reinforcement (assume $A_{steel}$ = 1.5% of A)
5. Concrete
6. Preparation of CSL (Cross Sonic Logging) tests requires the installation of 6 schedule 40 tubes all the way to the tip (attached to the reinforcement cage)
7. Equipment mobilization

For the driven pile construction consider the following costs:

1. Excavation (assume slope 1.5H:1V) and soil disposal for pile cap
2. Piles
3. Pile driving
4. Pile concreting
5. Construction of pile cap (compaction, forms, reinforcement, concrete)
6. Refill and compaction above and around pile cap to final grade

Make sure to provide all assumptions and details of unit price, volume, total price, and source of data and assumptions. Provide your results in tabulated summaries. You can provide ranges of prices and details in one table, and finalized itemized cost of major components and total figures in another table.