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Soils Report 2009-32 Addendum #1

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Subject: Soils Report No. 2009-32
Jock Stream Bridge
Revised Settlement Calculations
and Downdrag Evaluation
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Route: N/A
PIN: 16716.00
Town: Monmouth

The following revisions are made to the Geotechnical Design Report for the Replacement of Jock Stream Bridge over Jock Stream, Monmouth, Maine, Soils Report No. 2009-32:

During the PDR review process for the Jock Stream Bridge replacement project the design team was directed to raise the roadway grade along the existing causeway and at the bridge structure by as much as 2.25 feet. As a result of this increase in fill material, the original settlement calculations conducted in the Geotechnical Design Report dated November 16, 2009 were revised. The increased fill resulted in settlements which exceed 0.4 inches creating a fully developed downdrag condition for the proposed abutment piles. The following paragraphs present the revised evaluation of site conditions in light of this additional fill.

Settlement

The vertical alignment at the bridge will be raised approximately 2.25 feet at the west abutment and approximately 2.0 feet at the east abutment. The soils at the site are compressible and are susceptible to consolidation if the in-situ stresses are increased above the current levels (i.e., consolidation will occur if fill is placed or if structures are supported on compressible soils). Evaluation of the potential settlement due to the placement of up to 2.25 feet of fill resulted in approximately 1.2 inch of settlement. This settlement is anticipated to occur over a long period of time (32 years) and may require attention by a maintenance crew along the causeway.

Downdrag

Settlement analyses indicate that approximately 1.2 inches of settlement will occur at the site due to the placement of up to 2.25 feet of fill. Studies indicate that settlements in excess of 0.4 inches in soils where driven piles are present will result in downdrag (negative skin friction) forces on piles. The magnitude of downdrag has been estimated based on the effective vertical stress and empirical β factors obtained from full scale tests. The calculated downdrag values are:

Pile Section	Unfactored Downdrag Loads (DD) (kips)
HP 12 x 53	84
HP 12 x 74	86
HP 14 x 73	100
HP 14 x 89	101
HP 14 x 117	103

Calculations for the pile downdrag loads are attached to this memorandum. Based on past practice, it is recommended that a load factor, γ_p=1.0, is applied to downdrag forces in cohesive and cohesionless downdrag zones.

Construction Recommendations

Downdrag forces can be handled or reduced by using one or more of the following techniques:

- Reduce soil settlement by preloading the soil
- Use light weight fill materials
- Increase allowable pile stresses
- Prevent direct contact between soil and pile by use of a pile sleeve

Due to the planned design using friction piles, the use of bitumen coating to reduce the downdrag forces is not recommended for this site.

Settlement Analyses:

Reference: FHWA Soils and Foundations Reference Manual - Volume 1 (FHWA NHI-06-088) Hough pg 7-16

The roadway grade at centerline may be raised by as much as 0.5 feet .
Look at a simplified soil profile based on BB-MJS-101:

Finished Grade

Proposed Fill - Look at 2.25 feet of fill
N = 25 bpf (medium dense)
γ = 125 pcf

Existing Grade

Existing Fill/Native sand - fine to coarse sand

$H_1 := 9.0 \cdot ft$ $\quad \gamma_{sand} := 125 \cdot pcf$ $\quad N_{sand1} := 10$

Groundwater at top of silt

$\gamma_w := 62.4pcf$

Silt - Su=450 psf (soft)
Total Layer height: H = 43.0 ft - divide into 5 layers

$H_2 := 43.0 \cdot ft$

$H_{2silt1} := 7.0 \cdot ft$ $\quad \gamma_{silt} := 115 \cdot pcf$ $\quad N_{silt1} := 9$

$H_{2silt2} := 9.0 \cdot ft$ $\quad N_{silt2} := 1$

$H_{2silt3} := 9.0 \cdot ft$ $\quad N_{silt3} := 1$

$H_{2silt4} := 9.0 \cdot ft$ $\quad N_{silt4} := 1$

$H_{2silt5} := 9.0 \cdot ft$ $\quad N_{silt5} := 1$

Clayey Silt - Su=650 psf (medium stiff)
Total Layer height: H = 40.0 ft - divide into 4 layers

$H_3 := 40.0 \cdot ft$

$H_{3claysilt1} := 10.0 \cdot ft$ $\quad \gamma_{claysilt} := 115 \cdot pcf$ $\quad C_{c\_claysilt1} := 0.3514$ $\quad C_{r\_claysilt1} := 0.04$ $\quad e_{oclaysilt1} := 1.0$

$H_{3claysilt2} := 10.0 \cdot ft$ $\quad C_{c\_claysilt2} := 0.3514$ $\quad C_{r\_claysilt2} := 0.04$ $\quad e_{oclaysilt2} := 1.0$

$H_{3claysilt3} := 10.0 \cdot ft$ $\quad C_{c\_claysilt3} := 0.3174$ $\quad C_{r\_claysilt3} := 0.0463$ $\quad e_{oclaysilt3} := 0.94$

$H_{3claysilt4} := 10.0 \cdot ft$ $\quad C_{c\_claysilt4} := 0.3043$ $\quad C_{r\_claysilt4} := 0.0374$ $\quad e_{oclaysilt4} := 1.13$

Glacial Till - Sand - fine sand, medium dense

$H_4 := 40.0 \cdot ft$ $\quad \gamma_{sand} := 125 \cdot pcf$ $\quad N_{sand2} := 15$

LOADING ON AN INFINITE STRIP
VERTICAL EMBANKMENT LOADING

Project Name: Jock Stream Bridge
Project Number : 16716.00
Date: 06/22/10

Client: Monmouth
Project Manager : Benoit
Computed by: km

Embank. slope a = 10.00(ft)
Embank. width b = 27.00(ft)
p load/unit area = 280.00(psf)

INCREMENT OF STRESSES FOR Z-DIRECTION
X = 20.00(ft)

Z (ft)	Vert. Δz (psf)
0.00	280.00
4.00	270.85
8.00	240.55
12.00	207.61
16.00	179.42
20.00	156.47
24.00	137.90
28.00	122.79
32.00	110.38
36.00	100.06
40.00	91.39
44.00	84.02
48.00	77.70
52.00	72.23
56.00	67.45
60.00	63.24
64.00	59.52
68.00	56.20
72.00	53.22
76.00	50.53
80.00	48.10
84.00	45.89
88.00	43.87
92.00	42.02
96.00	40.31
100.00	38.74
104.00	37.28
108.00	35.93
112.00	34.67

at 4.5 ft

$\Delta\sigma_{zsand1} := 267.86 \cdot psf$

at 12.5 ft

$\Delta\sigma_{zsilt1} := 203.78 \cdot psf$

at 20.5 ft

$\Delta\sigma_{zsilt2} := 153.93 \cdot psf$

at 29.5 ft

$\Delta\sigma_{zsilt3} := 117.86 \cdot psf$

at 38.5 ft

$\Delta\sigma_{zsilt4} := 94.74 \cdot psf$

at 47.5 ft

$\Delta\sigma_{zsilt5} := 78.44 \cdot psf$

at 57.0 ft

$\Delta\sigma_{zclaysilt1} := 66.35 \cdot psf$

at 67.0 ft

$\Delta\sigma_{zclaysilt2} := 56.99 \cdot psf$

at 77.0 ft

$\Delta\sigma_{zclaysilt3} := 49.90 \cdot psf$

at 87.0 ft

$\Delta\sigma_{zclaysilt4} := 44.36 \cdot psf$

at 112.0 ft

$\Delta\sigma_{zsand2} := 34.67 \cdot psf$

Existing Fill/Sand

$tsf := psf \cdot 1000$

Determine corrected N-value normalized for overburden $N1_{60}$:

Calculate vertical stress: $\sigma_{sand1o} := \frac{H_1}{2} \cdot (\gamma_{sand})$ $\sigma_{sand1o} = 0.563 \cdot tsf$ at mid-point

Corrected SPT N_{60}-value (bpf) $N_{sand1} = 10$

At P_o = 0.563 tsf $C_{Nsand1} := 0.77 \cdot \log\left(\frac{40 \cdot ksf}{\sigma_{sand1o}}\right)$ Eq. 10.4.6.2.4 LRFD

$C_{Nsand1} = 1.426$

Corrected N-value normalized for overburden $N1_{60}$: $N1_{60} := C_{Nsand1} \cdot N_{sand1}$ $N1_{60} = 14$
From Eq 3-3 pg 3-36

From Figure 7-7 pg 7-17 using the "clean well graded fine to coarse sand" curve

Bearing Capacity Index: $C1 := 57$

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$\Delta\sigma_{zsand1} = 267.86 \cdot psf$

Silt - 5 layers

Silt Layer 1:

Determine corrected N-value normalized for overburden $N1_{60}$:

Calculate vertical stress: $\sigma_{silt1o} := \left[\frac{H_{2silt1}}{2} \cdot (\gamma_{silt} - \gamma_w)\right] + H_1 \cdot (\gamma_{sand})$ $\sigma_{silt1o} = 1.309 \cdot tsf$ at mid-point

Corrected SPT N_{60}-value (bpf) $N_{silt1} = 9$

At P_o = 1.3 tsf $C_{Nsilt1} := 0.77 \cdot \log\left(\frac{40 \cdot ksf}{\sigma_{silt1o}}\right)$ Eq. 10.4.6.2.4 LRFD

$C_{Nsilt1} = 1.144$

Corrected N-value normalized for overburden $N1_{60}$: $N1_{60} := C_{Nsilt1} \cdot N_{silt1}$ $N1_{60} = 10$
From Eq 3-3 pg 3-36

From Figure 7-7 pg 7-17 using the "Inorganic silt" curve

Bearing Capacity Index: $C2_{silt1} := 29$

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$\Delta\sigma_{zsilt1} = 203.78 \cdot psf$

Silt Layer 2:

Determine corrected N-value normalized for overburden $N1_{60}$:

Calculate vertical stress:

$$\sigma_{silt2o} := \left[\frac{H_{2silt2}}{2}\cdot(\gamma_{silt}-\gamma_w)\right] + H_{2silt1}\cdot(\gamma_{silt}-\gamma_w) + H_1\cdot(\gamma_{sand}) \qquad \sigma_{silt2o} = 1.73\cdot tsf$$

at mid-point

Corrected SPT N_{60}-value (bpf) $\quad N_{silt2} = 1$

At P_o = 1.7 tsf

$$C_{Nsilt2} := 0.77\cdot\log\left(\frac{40\cdot ksf}{\sigma_{silt2o}}\right)$$

Eq. 10.4.6.2.4 LRFD

$$C_{Nsilt2} = 1.05$$

Corrected N-value normalized for overburden $N1_{60}$: $\quad N1_{60} := C_{Nsilt2}\cdot N_{silt2} \qquad N1_{60} = 1$
From Eq 3-3 pg 3-36

From Figure 7-7 pg 7-17 using the "Inorganic silt" curve

Bearing Capacity Index: $\quad C2_{silt2} := 17$

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$$\Delta\sigma_{zsilt2} = 153.93\cdot psf$$

Silt Layer 3:

Determine corrected N-value normalized for overburden $N1_{60}$:

Calculate vertical stress:

$$\sigma_{silt3o} := \left[\frac{H_{2silt3}}{2}\cdot(\gamma_{silt}-\gamma_w)\right] + (H_{2silt2}+H_{2silt1})\cdot(\gamma_{silt}-\gamma_w) + H_1\cdot(\gamma_{sand}) \qquad \sigma_{silt3o} = 2.203\cdot tsf$$

at mid-point

Corrected SPT N_{60}-value (bpf) $\quad N_{silt3} = 1$

At P_o = 2.2 tsf

$$C_{Nsilt3} := 0.77\cdot\log\left(\frac{40\cdot ksf}{\sigma_{silt3o}}\right)$$

Eq. 10.4.6.2.4 LRFD

$$C_{Nsilt3} = 0.969$$

Corrected N-value normalized for overburden $N1_{60}$: $\quad N1_{60} := C_{Nsilt3}\cdot N_{silt3} \qquad N1_{60} = 1$
From Eq 3-3 pg 3-36

From Figure 7-7 pg 7-17 using the "Inorganic silt" curve

Bearing Capacity Index: $\quad C2_{silt3} := 15$

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$$\Delta\sigma_{zsilt3} = 117.86\cdot psf$$

Silt Layer 4:

Determine corrected N-value normalized for overburden $N1_{60}$:

Calculate vertical stress:

$$\sigma_{silt4o} := \left[\frac{H_{2silt4}}{2}\cdot(\gamma_{silt}-\gamma_w)\right] + (H_{2silt3}+H_{2silt2}+H_{2silt1})\cdot(\gamma_{silt}-\gamma_w) + H_1\cdot(\gamma_{sand}) \quad \sigma_{silt4o} = 2.677\cdot tsf$$

at mid-point

Corrected SPT N_{60}-value (bpf) $N_{silt4} = 1$

At P_o = 2.7 tsf

$$C_{Nsilt4} := 0.77\cdot\log\left(\frac{40\cdot ksf}{\sigma_{silt4o}}\right)$$

Eq. 10.4.6.2.4 LRFD

$$C_{Nsilt4} = 0.904$$

Corrected N-value normalized for overburden $N1_{60}$: $N1_{60} := C_{Nsilt4}\cdot N_{silt4}$ $N1_{60} = 1$
From Eq 3-3 pg 3-36

From Figure 7-7 pg 7-17 using the "Inorganic silt" curve

Bearing Capacity Index: $C2_{silt4} := 15$

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$$\Delta\sigma_{zsilt4} = 94.74\cdot psf$$

Silt Layer 5:

Determine corrected N-value normalized for overburden $N1_{60}$:

Calculate vertical stress:

$$\sigma_{silt5o} := \left[\frac{H_{2silt5}}{2}\cdot(\gamma_{silt}-\gamma_w)\right] + (H_{2silt4}+H_{2silt3}+H_{2silt2}+H_{2silt1})\cdot(\gamma_{silt}-\gamma_w) + H_1\cdot(\gamma_{san} \quad \sigma_{silt5o} = 3.15\cdot tsf$$

at mid-point

Corrected SPT N_{60}-value (bpf) $N_{silt5} = 1$

At P_o = 3.2 tsf

$$C_{Nsilt5} := 0.77\cdot\log\left(\frac{40\cdot ksf}{\sigma_{silt5o}}\right)$$

Eq. 10.4.6.2.4 LRFD

$$C_{Nsilt5} = 0.85$$

Corrected N-value normalized for overburden $N1_{60}$: $N1_{60} := C_{Nsilt5}\cdot N_{silt5}$ $N1_{60} = 1$
From Eq 3-3 pg 3-36

From Figure 7-7 pg 7-17 using the "Inorganic silt" curve

Bearing Capacity Index: $C2_{silt5} := 15$

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$$\Delta\sigma_{zsilt5} = 78.44\cdot psf$$

Clayey Silt - 4 layers

Clayey Silt Layer 1:

Average values from lab data: $e_{oclavsilt1} = 1$ $C_{r\ clavsilt1} = 0.04$

$$\sigma_{claysilt1o} := \frac{H_{3claysilt1}}{2} \cdot (\gamma_{claysilt} - \gamma_w) + H_2 \cdot (\gamma_{silt} - \gamma_w) + H_1 \cdot (\gamma_{sand})$$ $\sigma_{claysilt1o} = 3.65 \cdot tsf$ at mid-point

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$\Delta\sigma_{zclaysilt1} = 66.35 \cdot psf$

Clayey Silt Layer 2:

Average values from lab data: $e_{oclavsilt2} = 1$ $C_{r\ clavsilt2} = 0.04$

$$\sigma_{claysilt2o} := \frac{H_{3claysilt2}}{2} \cdot (\gamma_{claysilt} - \gamma_w) + H_{3claysilt1} \cdot (\gamma_{claysilt} - \gamma_w) + H_2 \cdot (\gamma_{silt} - \gamma_w) + H_1 \cdot (\gamma_{sand})$$

$\sigma_{claysilt2o} = 4.18 \cdot tsf$ at mid-point

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$\Delta\sigma_{zclaysilt2} = 56.99 \cdot psf$

Clayey Silt Layer 3:

Average values from lab data: $e_{oclavsilt3} = 0.94$ $C_{r\ clavsilt3} = 0.046$

$$\sigma_{claysilt3o} := \frac{H_{3claysilt3}}{2} \cdot (\gamma_{claysilt} - \gamma_w) + (H_{3claysilt2} + H_{3claysilt1}) \cdot (\gamma_{claysilt} - \gamma_w) + H_2 \cdot (\gamma_{silt} - \gamma_w) + H_1 \cdot (\gamma_{sand})$$

$\sigma_{claysilt3o} = 4.7 \cdot tsf$ at mid-point

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$\Delta\sigma_{zclaysilt3} = 49.9 \cdot psf$

Clayey Silt Layer 4:

Average values from lab data: $e_{oclavsilt4} = 1.13$ $C_{r\ clavsilt4} = 0.037$

$$\sigma_{claysilt4o} := \frac{H_{3claysilt4}}{2} \cdot (\gamma_{claysilt} - \gamma_w) + (H_{3claysilt3} + H_{3claysilt2} + H_{3claysilt1}) \cdot (\gamma_{claysilt} - \gamma_w) + H_2 \cdot (\gamma_{silt} - \gamma_w) + H_1 \cdot (\gamma$$

$\sigma_{claysilt4o} = 5.23 \cdot tsf$ at mid-point

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$\Delta\sigma_{zclaysilt4} = 44.36 \cdot psf$

Glacial Till - Sand

Determine corrected N-value normalized for overburden $N1_{60}$:

Calculate vertical stress:

$$\sigma_{sand2o} := \frac{H_4}{2}(\gamma_{sand} - \gamma_w) + H_3 \cdot (\gamma_{claysilt} - \gamma_w) + H_2 \cdot (\gamma_{silt} - \gamma_w) + H_1 \cdot (\gamma_{sand})$$

$\sigma_{sand2o} = 6.743 \cdot tsf$ at mid-point

Corrected SPT N_{60}-value (bpf) $N_{sand2} = 15$

AT P_o = 6.7 tsf

$$C_{Nsand2} := 0.77 \cdot \log\left(\frac{40 \cdot ksf}{\sigma_{sand2o}}\right)$$ Eq. 10.4.6.2.4 LRFD

$C_{Nsand2} = 0.595$

Corrected N-value normalized for overburden $N1_{60}$:
From Eq 3-3 pg 3-36 $N1_{60} := C_{Nsand2} \cdot N_{sand2}$ $N1_{60} = 9$

From Figure 7-7 pg 7-17 using the "clean well graded fine to coarse sand" curve

Bearing Capacity Index: $C4_{sand2} := 47$

Use STRESS to determine the change in stress at the mid point of the layer under consideration (above)

$\Delta\sigma_{zsand2} = 34.67 \cdot psf$

Calculate Settlement:

Fill/Sand: $$\Delta H_1 := H_1 \cdot \frac{1}{C1} \cdot \log\left(\frac{\sigma_{sand1o} + \Delta\sigma_{zsand1}}{\sigma_{sand1o}}\right)$$ $\Delta H_1 = 0.32 \cdot in$

Silt Layer 1: $$\Delta H_{2silt1} := H_{2silt1} \cdot \frac{1}{C2_{silt1}} \cdot \log\left(\frac{\sigma_{silt1o} + \Delta\sigma_{zsilt1}}{\sigma_{silt1o}}\right)$$ $\Delta H_{2silt1} = 0.182 \cdot in$

Silt Layer 2: $$\Delta H_{2silt2} := H_{2silt2} \cdot \frac{1}{C2_{silt2}} \cdot \log\left(\frac{\sigma_{silt2o} + \Delta\sigma_{zsilt2}}{\sigma_{silt2o}}\right)$$ $\Delta H_{2silt2} = 0.235 \cdot in$

Silt Layer 3: $$\Delta H_{2silt3} := H_{2silt3} \cdot \frac{1}{C2_{silt3}} \cdot \log\left(\frac{\sigma_{silt3o} + \Delta\sigma_{zsilt3}}{\sigma_{silt3o}}\right)$$ $\Delta H_{2silt3} = 0.163 \cdot in$

Silt Layer 4: $$\Delta H_{2silt4} := H_{2silt4} \cdot \frac{1}{C2_{silt4}} \cdot \log\left(\frac{\sigma_{silt4o} + \Delta\sigma_{zsilt4}}{\sigma_{silt4o}}\right)$$ $\Delta H_{2silt4} = 0.109 \cdot in$

Silt Layer 5: $$\Delta H_{2silt5} := H_{2silt5} \cdot \frac{1}{C2_{silt5}} \cdot \log\left(\frac{\sigma_{silt5o} + \Delta\sigma_{zsilt5}}{\sigma_{silt5o}}\right)$$ $\Delta H_{2silt5} = 0.077 \cdot in$

Clayey Silt Layer 1: $$\Delta H_{3cs1} := H_{3claysilt1} \cdot \left(\frac{C_{r\_claysilt1}}{1 + e_{oclaysilt1}}\right) \cdot \log\left(\frac{\sigma_{claysilt1o} + \Delta\sigma_{zclaysilt1}}{\sigma_{claysilt1o}}\right)$$ $\Delta H_{3cs1} = 0.019 \cdot in$

Clayey Silt Layer 2: $\Delta H_{3cs2} := H_{3claysilt2} \cdot \left(\frac{C_{r\_claysilt2}}{1 + e_{oclaysilt2}}\right) \cdot \log\left(\frac{\sigma_{claysilt2o} + \Delta\sigma_{zclaysilt2}}{\sigma_{claysilt2o}}\right)$ $\Delta H_{3cs2} = 0.014 \cdot in$

Clayey Silt Layer 3: $\Delta H_{3cs3} := H_{3claysilt3} \cdot \left(\frac{C_{r\_claysilt3}}{1 + e_{oclaysilt3}}\right) \cdot \log\left(\frac{\sigma_{claysilt3o} + \Delta\sigma_{zclaysilt3}}{\sigma_{claysilt3o}}\right)$ $\Delta H_{3cs3} = 0.013 \cdot in$

Clayey Silt Layer 4: $\Delta H_{3cs4} := H_{3claysilt4} \cdot \left(\frac{C_{r\_claysilt4}}{1 + e_{oclaysilt4}}\right) \cdot \log\left(\frac{\sigma_{claysilt4o} + \Delta\sigma_{zclaysilt4}}{\sigma_{claysilt4o}}\right)$ $\Delta H_{3cs4} = 0.008 \cdot in$

Glacial Till - Sand: $\Delta H_4 := H_4 \cdot \frac{1}{C4_{sand2}} \cdot \log\left(\frac{\sigma_{sand2o} + \Delta\sigma_{zsand2}}{\sigma_{sand2o}}\right)$ $\Delta H_4 = 0.023 \cdot in$

Total Settlement =

$$\Delta H_T := \Delta H_1 + \Delta H_{2silt1} + \Delta H_{2silt2} + \Delta H_{2silt3} + \Delta H_{2silt4} + \Delta H_{2silt5} + \Delta H_{3cs1} + \Delta H_{3cs2} + \Delta H_{3cs3} + \Delta H_{3cs4} + \Delta H_4$$

$\Delta H_T = 1.163 \cdot in$

With 1.2 inches of settlement downdrag forces will be fully developed.

Elastic Settlement = $\Delta H_1 + \Delta H_4 = 0.343 \cdot in$

Consolidation Settlement = $\Delta H_{2silt1} + \Delta H_{2silt2} + \Delta H_{2silt3} + \Delta H_{2silt4} + \Delta H_{2silt5} + \Delta H_{3cs1} + \Delta H_{3cs2} + \Delta H_{3cs3} + \Delta H_{3cs4} = 0.8 \cdot in$

Time Rate of Settlement:

Determine the time for 90% consolidation for primary settlement
Reference: FHWA Soils and Foundation Reference Manual - Volume 1 page 7-30

Thickness of the silt/clay layer = $H_{siltclay} := 83.0 \cdot ft$

Assume double drainage due to presence of sand layers above and below the clay layer.

$H_{scv} := 41.5 \cdot ft$

Time factor from Table on page 7-32
At 90% primary consolidation $T_v := 0.848$

Coefficient of consolidation from lab data: $C_v := 1.46 \cdot 10^{-6} \cdot \frac{ft^2}{sec}$ $C_v = 0.126 \cdot \frac{ft^2}{day}$

Time rate of settlement to achieve 90% Primary Consolidation

$t_{90} := \frac{T_v \cdot H_{scv}^2}{C_v}$ $t_{90} = 1.1578 \times 10^4 \cdot day$ $year := 365 \cdot day$

$t_{90} = 31.72 \cdot year$

Determination of Downdrag:

Use beta method to determine downdrag

Granular soil (Sandford) $\beta_{gr} := 0.11$

Silt/Clay (Sandford), Presumpscot formation $\beta_{clay} := 0.06$

Assumed values

Unit weight of existing sand fill $\gamma_{sand} := 125 \cdot pcf$

Groundwater table at top of silt layer

Unit weight of water $\gamma_w := 62.4 \cdot pcf$

Unit weight of silt/clay $\gamma_{siltclay} := 115 \cdot pcf$

Effective unit weight of silt/clay $\gamma'_{siltclay} := \gamma_{siltclay} - \gamma_w$ $\gamma'_{siltclay} = 52.6 \cdot pcf$

Stress from overburden material. Overburden consists of approximately 9 feet of sand on 43 feet of silt fill on 40 feet of clayey silt all over glacial till. Water table is at the top of the silt layer.

Change in overburden Stress due to fill = $\sigma_{v\_ob} := 2.25 \cdot ft \cdot \gamma_{sand}$ $\sigma_{v\_ob} = 281.25 \cdot psf$

at 4.5 ft $\Delta\sigma_{4.5} := 267.86 \cdot psf$

at 30.5 ft $\Delta\sigma_{30.5} := 130.54 \cdot psf$

at 72.0 ft $\Delta\sigma_{72} := 53.22 \cdot psf$

Effective vertical stress in middle of each layer

Total thickness of each stratum

$D_{sand} := 9 \cdot ft$ $D_{silt} := 43 \cdot ft$ $D_{claysilt} := 40ft$

$$\sigma'_{v\_sand} := \Delta\sigma_{4.5} + \frac{D_{sand}}{2} \cdot \gamma_{sand} \qquad \sigma'_{v\_sand} = 830.4 \cdot psf$$

$$\sigma'_{v\_silt} := \Delta\sigma_{30.5} + D_{sand} \cdot \gamma_{sand} + \frac{D_{silt}}{2} \cdot \gamma_{silt} \qquad \sigma'_{v\_silt} = 3728 \cdot psf$$

$$\sigma'_{v\_claysilt} := \Delta\sigma_{72} + D_{sand} \cdot \gamma_{sand} + D_{silt} \cdot (\gamma_{silt} - \gamma_w) + \frac{D_{claysilt}}{2} \cdot (\gamma_{siltclay} - \gamma_w) \qquad \sigma'_{v\_claysilt} = 4492 \cdot psf$$

Pile parameters:

Look at these piles:

HP 12 x 53
HP 12 x 74
HP 14 x 73
HP 14 x 89
HP 14 x 117

Note: All matrices set up in this order

Steel area:

$$A_s := \begin{pmatrix} 15.5 \\ 21.8 \\ 21.4 \\ 26.1 \\ 34.4 \end{pmatrix} \cdot in^2$$

Pile depth:

$$d := \begin{pmatrix} 11.78 \\ 12.13 \\ 13.61 \\ 13.83 \\ 14.21 \end{pmatrix} \cdot in$$

Pile width:

$$b := \begin{pmatrix} 12.045 \\ 12.215 \\ 14.585 \\ 14.695 \\ 14.885 \end{pmatrix} \cdot in$$

Box perimeter: $P := 2 \cdot (d + b)$

$$P = \begin{pmatrix} 47.65 \\ 48.69 \\ 56.39 \\ 57.05 \\ 58.19 \end{pmatrix} \cdot in$$

Magnitude of maximum downdrag, considered over entire clay thickness

$$Q_{dd} := \left(D_{sand} \cdot \sigma'_{v\_sand} \cdot \beta_{gr} + D_{silt} \cdot \sigma'_{v\_silt} \cdot \beta_{clay} + D_{claysilt} \cdot \sigma'_{v\_claysilt} \cdot \beta_{clay}\right) \cdot P$$

$$Q_{dd} = \begin{pmatrix} 84 \\ 86 \\ 100 \\ 101 \\ 103 \end{pmatrix} \cdot kip$$

For these piles:

HP 12 x 53
HP 12 x 74
HP 14 x 73
HP 14 x 89
HP 14 x 117

Based on past practice in the estimation of downdrag forces in Maine, a downdrag load factor of 1.0 is recommended