



Client: ODOT/District 6
Project: FRA-70 Project 4B
Subject: 4th Street Bridge Rear Abutment Wingwall Design
Bridge No. FRA-23-1075C

Job No.: 2015370
Page No.: 1 Of 3
Designed: MLS Date: 5/9/2019
Checked: MOJ Date: 7/11/2022

| | | |
|--|---|-----------|
| Arm 7 = $(H_1 + H_2) / 2 =$ | (27.26 ft. + 3.00 ft.) / 2.00 = | 15.13 ft. |
| Area 8 = $0.5 \times \gamma_c \times W_{w1} \times H_{w1} =$ | $0.5 \times 0.150 \text{ kcf} \times 0.00 \text{ ft.} \times 27.01 \text{ ft.} \times 1.00 \text{ ft.} =$ | 0.00 kips |
| Arm 8 = $W_{toe} + W_w + W_{w1} / 3 =$ | $5.25 \text{ ft.} + 4.21 \text{ ft.} + 0.00 \text{ ft.} / 3.00 =$ | 9.46 ft. |

Force and Moment Arm Calculations (Continued):

| | | |
|--|--|-----------|
| Area 9 = $0.5 \times \gamma_c \times W_{w1} \times H_{w1} =$ | $0.5 \times 0.120 \text{ kcf} \times 0.00 \text{ ft.} \times 27.01 \text{ ft.} \times 1.00 \text{ ft.} =$ | 0.00 kips |
| Arm 9 = $W_{toe} + W_w + W_{w1} / 2 / 3 =$ | $5.25 \text{ ft.} + 4.21 \text{ ft.} + 0.00 \text{ ft.} \times 2.00 / 3.00 =$ | 9.46 ft. |
| Area 10 = $0.5 \times \gamma_c \times (S_d \times W_{h1}) \times W_{h1} =$ | $0.5 \times 0.120 \text{ kcf} \times (0.00 \times 7.04 \text{ ft.}) \times 7.04 \text{ ft.} \times 1.00 \text{ ft.} =$ | 0.00 kips |
| Arm 10 = $W_F - W_{h1} / 3 =$ | $16.50 \text{ ft.} - 7.04 \text{ ft.} / 3.00 =$ | 14.15 ft. |
| Area 11 = $F_d =$ | 0.00 kips | 0.00 kips |
| Surcharge on Heel = $\gamma_{soil} \times LLS \times W_h \times H_s =$ | $0.125 \text{ kcf} \times 7.04 \text{ ft.} \times 2.00 \text{ ft.} \times 1.00 \text{ ft.} =$ | 1.76 kips |
| Arm for Heel Surcharge = $W_F - W_{h1} / 2 =$ | $16.50 \text{ ft.} - 7.04 \text{ ft.} / 2.00 =$ | 12.98 ft. |
| Surcharge on Toe = $\gamma_{soil} \times LLS \times W_{toe} \times H_{st} =$ | $0.125 \text{ kcf} \times 5.25 \text{ ft.} \times 4.19 \text{ ft.} \times 1.00 \text{ ft.} =$ | 2.75 kips |
| Arm for Toe Surcharge = $W_{toe} / 2 =$ | $5.25 \text{ ft.} / 2.00 =$ | 2.63 ft. |

Check Bearing Pressure:

per BDM 307.1.5 and LRFD 11.6.3.2.

Factored Bearing Resistance = 12.70 ksf

Maximum Strength Load Pressures:

Bearing pressure at Toe = 6.21 ksf OK
Bearing pressure at Heel = 6.21 ksf OK

Check Eccentricity:

per BDM 307.1.4 and LRFD 11.6.3.3.

Maximum Allowable $e = B/3 = 5.50 \text{ ft}$
Controlling Eccentricity = 2.58 ft OK

Check Sliding:

per BDM 307.1.3 and LRFD 11.6.3.6.

Resistance factor, ϕ_r (Sliding) = 1.00 LRFD Table 11.5.7-1

Resistance factor, ϕ_{ep} (Passive pressure) = 0.50 LRFD Table 10.5.5.2.2-1

Sliding Resistance:

Unfactored Horizontal Sliding Resistance = 35.46 kips
Factored Horizontal Sliding Resistance = 35.46 kips

Passive Resistance on Footing Toe:

Unfactored Passive Resistance = 0.00 kips
Factored Passive Resistance = 0.00 kips

Passive Resistance on Footing Key or Sheet Piling (Below bottom of Footing):

Vertical Projection Below Footing = 0.00 ft

Pressure at Bottom of Footing (P_4) = 2.77 ksf
Pressure at Bottom of Disturbance (P_6) = 0.96 ksf
Pressure at Bottom of Key or Sheet Piling = 2.77 ksf

Unfactored Passive Resistance = 0.00 kips
Factored Passive Resistance = 0.00 kips

Total Factored Resisting Force = 35.46 kips
Driving Force = 26.96 kips OK

Check Settlement:

Service Bearing Capacity = 4.48 ksf
Service Bearing Pressure at Toe = 4.35 ksf OK
Service Bearing Pressure at Heel = 4.35 ksf OK

Summary of Load Effects:

| | MAX. BEARING PRESSURE | MIN. BEARING PRESSURE | ECCENTRICITY MAX. LF | ECCENTRICITY MIN. LF | SLIDING FORCES MAX. LF | VERTICAL FORCES MIN. LF |
|------------|-----------------------|-----------------------|----------------------|----------------------|------------------------|-------------------------|
| STRENGTH I | 6.21 | 6.21 | 1.86 | 2.58 | 26.96 | 56.75 |
| SERVICE I | 4.35 | 4.35 | 1.41 | N/A | 17.60 | 56.49 |

Load Modification Factors:

LRFD 1.3.3, LRFD 1.3.4, LRFD 1.3.5, & BDM 1001

Ductility $\eta_D = 1.00$ (use 1.00 for all limit states)
Redundancy $\eta_R = 1.00$ (use 1.00 for redundant structures and 1.05 for non-redundant structures)
Operational importance $\eta_I = 1.00$ (use 1.00 for all limit states)



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STRENGTH I Load Combination

Sliding Forces & Overturning Moments

1.50*EH+1.75*LS(H). Ignores resisting moments from passive force on toe/key/sheeting, which is conservative.

ΣM about point "A"

| Area/Force | Unfactored Load | Load Factor | Force (k) | Moment Arm (ft) | Moment (k-ft) Max. Load Factor | |
|------------------------------------|-----------------|-------------|------------|-------------------------|-----------------------------------|---------------|
| 6 (Horizontal comp.) | 15.35 | 1.50 | 23.02 | 10.09 | 232.24 | Horiz. Forces |
| 7 | 2.25 | 1.75 | 3.94 | 15.13 | 59.55 | |
| Σ Sliding Forces, F _s = | | | 26.96 kips | Σ Overturning Moments = | | 291.79 k*ft. |

Vertical Forces & Resisting Moments

1.5*DC+1.35*EV+1.75*LS_v (Max.) 0.9*DC+1.0*EV (Min.)

ΣM about point "A"

| This column is for stability | | | | | | | | | | This column is for stability | |
|------------------------------|-----------------|------------------|------------------|------------------|------------------|-----------------|------------------|---------------------|---|------------------------------|--------------|
| | Force (k) | | Force (k) | | Force (k) | | Moment (k-ft) | | Moment (k-ft) | | |
| Area/Force | Unfactored Load | Max. Load Factor | Max. Load Factor | Min. Load Factor | Min. Load Factor | Moment Arm (ft) | Max. Load Factor | Min. Load Factor | | | |
| 1 | 19.10 | 1.25 | 23.88 | 0.90 | 17.19 | 7.35 | 175.60 | 126.43 | Dead Loads From Concrete | | |
| 2 | 3.17 | 1.25 | 3.96 | 0.90 | 2.85 | 12.98 | 51.41 | 37.01 | | | |
| 3 | 2.56 | 1.25 | 3.20 | 0.90 | 2.30 | 2.63 | 8.40 | 6.05 | | | |
| 8 | 0.00 | 1.25 | 0.00 | 0.90 | 0.00 | 9.46 | 0.00 | 0.00 | | | |
| 4 | 22.82 | 1.35 | 30.81 | 1.00 | 22.82 | 12.98 | 399.91 | 296.23 | Dead Loads | | |
| 5 (Max.) | 2.80 | 1.35 | 3.78 | 1.00 | 2.80 | 2.63 | 9.93 | 7.36 | From Soil (Do not include 5 (Min.) and 5 (Max.) simultaneously) | | |
| 5 (Min.) | 2.80 | 1.35 | 3.78 | 1.00 | 2.80 | 2.63 | 9.93 | 7.36 | | | |
| 6 (Vertical comp.) | 5.59 | 1.50 | 8.38 | 1.50 | 8.38 | 16.50 | 138.27 | 138.27 | | | |
| 9 | 0.00 | 1.35 | 0.00 | 1.00 | 0.00 | 9.46 | 0.00 | 0.00 | | | |
| 10 | 0.00 | 1.35 | 0.00 | 1.00 | 0.00 | 14.15 | 0.00 | 0.00 | | | |
| Surcharge on Heel | 1.76 | 1.75 | 3.08 | 0.00 | 0.00 | 12.98 | 39.99 | 0.00 | External Loads | | |
| Surcharge on Toe | 2.75 | 1.75 | 4.81 | 0.00 | 0.00 | 2.63 | 12.63 | 0.00 | | | |
| DC | 0.44 | 1.25 | 0.55 | 0.90 | 0.40 | 5.77 | 3.19 | 2.30 | | | |
| Σ Vert. Forces = | | | 82.46 kips | Σ Vert. Forces = | | | 56.75 kips | Σ Resist. Moments = | | 839.33 k*ft. | 613.65 k*ft. |

Note: Calculations for each controlling load case are not necessarily shown below, but have been included in the design checks.

| Max. Load Factor Calculations (Worst case bearing pressure shown.) | | Min. Load Factor Calculations (Worst case eccentricity shown.) | |
|--|--------------|--|--------------|
| Overturning Moment = Σ Overturning Moments = | 291.79 k-ft. | Overturning Moment = Σ Overturning Moments = | 291.79 k-ft. |
| Resisting Moment = Σ Max. Resisting Moments = | 839.33 k-ft. | Resisting Moment = Σ Min. Resisting Moments = | 613.65 k-ft. |
| Net Moment = Resisting Moment - Overturning Moment = | 547.54 k-ft. | Net Moment = Resisting Moment - Overturning Moment = | 321.86 k-ft. |
| Total Vertical Force (TVF) = Σ Vert. Forces = | 82.46 kips | Total Vertical Force (TVF) = Σ Vert. Forces = | 56.75 kips |
| Dist. from Point A (Ā) = Net. Moment / TVF = | 6.64 ft. | Dist. from Point A (Ā) = Net. Moment / TVF = | 5.67 ft. |
| Eccentricity "e" = (0.5*W _l) - Ā = | 1.61 ft. | Eccentricity "e" = (0.5*W _l) - Ā = | 2.58 ft. |
| Maximum Bearing Pressure = TVF/(Wf-2*e) = | 6.21 ksf | | |
| Minimum Bearing Pressure = TVF/(Wf+2*e) = | 6.21 ksf | | |

SERVICE I Load Combination

Sliding Forces & Overturning Moments

1.0*EH+1.0*LS_H. Ignores resisting moments from passive force on toe/key/sheeting, which is conservative.

ΣM about point "A"

| Area/Force | Unfactored Load | Load Factor | Force (k) | Moment Arm (ft) | Moment (k-ft) Max. Load Factor | |
|------------------------------------|-----------------|-------------|------------|-------------------------|-----------------------------------|---------------|
| 6 (Horizontal comp.) | 15.35 | 1.00 | 15.35 | 10.09 | 154.82 | Horiz. Forces |
| 7 | 2.25 | 1.00 | 2.25 | 15.13 | 34.03 | |
| Σ Sliding Forces, F _s = | | | 17.60 kips | Σ Overturning Moments = | | 188.85 k*ft. |

Vertical Forces & Resisting Moments

1.0*DC+1.0*EV+1.0*LS_v

ΣM about point "A"

| Area/Force | Force (k) | Load Factor | Force (k) | Moment Arm (ft) | Moment (k-ft) | |
|--------------------|-----------|-------------|------------|-----------------------|---------------|--|
| 1 | 19.10 | 1.00 | 19.10 | 7.35 | 140.48 | Dead Loads From Concrete |
| 2 | 3.17 | 1.00 | 3.17 | 12.98 | 41.13 | |
| 3 | 2.56 | 1.00 | 2.56 | 2.63 | 6.72 | |
| 8 | 0.00 | 1.00 | 0.00 | 9.46 | 0.00 | |
| 4 | 22.82 | 1.00 | 22.82 | 12.98 | 296.23 | Dead Loads From Soil (Do not include 5 (Min.) and 5 (Max.) simultaneously) |
| 5 (Max.) | 2.80 | 1.00 | 2.80 | 2.63 | 7.36 | |
| 5 (Min.) | 2.80 | 1.00 | 2.80 | 2.63 | 7.36 | |
| 6 (Vertical comp.) | 5.59 | 1.00 | 5.59 | 16.50 | 92.18 | |
| 9 | 0.00 | 1.00 | 0.00 | 9.46 | 0.00 | External Loads |
| 10 | 0.00 | 1.00 | 0.00 | 14.15 | 0.00 | |
| Surcharge on Heel | 1.76 | 1.00 | 1.76 | 12.98 | 22.85 | |
| Surcharge on Toe | 2.75 | 1.00 | 2.75 | 2.63 | 7.22 | |
| DC | 0.44 | 1.00 | 0.44 | 5.77 | 2.55 | |
| Σ Vert. Forces = | | | 61.00 kips | Σ Resisting Moments = | | 616.71 k*ft. |

Note: Calculations for each controlling load case are not necessarily shown below, but have been included in the design checks.

| Calculations for worst case bearing pressure shown. | |
|--|--------------|
| Overturning Moment = Σ Overturning Moments = | 188.85 k-ft. |
| Resisting Moment = Σ Max. Resisting Moments = | 616.71 k-ft. |
| Net Moment = Resisting Moment - Overturning Moment = | 427.86 k-ft. |
| Total Vertical Force (TVF) = Σ Vert. Forces = | 61.00 kips |
| Dist. from Point A (Ā) = Net. Moment / TVF = | 7.01 ft. |
| Eccentricity "e" = (0.5*W _l) - Ā = | 1.24 ft. |
| Maximum Bearing Pressure = TVF/(Wf-2*e) = | 4.35 ksf |
| Minimum Bearing Pressure = TVF/(Wf+2*e) = | 4.35 ksf |

• Where the wall is supported by a rock foundation:
the vertical stress shall be calculated assuming a linearly distributed pressure over an effective base area as shown in Figure 11.6.3.2-2. If the resultant is within the middle one-third of the base:
The vertical stress shall be calculated as follows:
$$\sigma_{max} = \frac{\Sigma V}{B} \left(1 + 6 \frac{e}{B} \right)$$
 (11.6.3.2-2)
$$\sigma_{min} = \frac{\Sigma V}{B} \left(1 - 6 \frac{e}{B} \right)$$
 (11.6.3.2-3)
where the variables are as defined in Figure 11.6.3.2-2. If the resultant is outside the middle one-third of the base:
$$\sigma_{max} = \frac{2 \Sigma V}{3(B/2 - e)}$$
 (11.6.3.2-4)
$$\sigma_{min} = 0$$
 (11.6.3.2-5)
where the variables are as defined in Figure 11.6.3.2-2.