

钢筋混凝土箱涵结构设计计算书 (K2+131.261处单孔箱涵)

一、设计资料

1、孔径及净空

$$\begin{aligned} \text{净跨径} \quad L_0 &= 6 \quad \text{m} \\ \text{净高} \quad h_0 &= 4 \quad \text{m} \end{aligned}$$

$$\begin{aligned} \text{2、设计安全等级} \quad & \text{二级} \\ \text{结构重要性系数} \quad r_0 &= 1.0 \end{aligned}$$

3、汽车荷载

$$\text{荷载等级} \quad \text{公路 — II 级}$$

4、填土情况

$$\begin{aligned} \text{涵顶填土高度} \quad H &= 5.9 \quad \text{m} \\ \text{土的内摩擦角} \quad \Phi &= 30^\circ \\ \text{填土容重} \quad \gamma_1 &= 18 \quad \text{kN/m}^3 \\ \text{地基容许承载力} \quad [\sigma_0] &= 200 \quad \text{kPa} \end{aligned}$$

5、建筑材料

$$\begin{aligned} \text{普通钢筋种类} \quad & \text{HRB400} \\ \text{主钢筋直径} \quad & 25 \quad \text{mm} \\ \text{钢筋抗拉强度设计值} \quad f_{sd} &= 360 \quad \text{MPa} \\ \text{涵身混凝土强度等级} \quad C &= 35 \\ \text{涵身混凝土抗压强度设计值} \quad f_{cd} &= 16.1 \quad \text{MPa} \\ \text{涵身混凝土抗拉强度设计值} \quad f_{td} &= 1.52 \quad \text{MPa} \\ \text{钢筋混凝土重力密度} \quad \gamma_2 &= 25 \quad \text{kN/m}^3 \\ \text{基础混凝土强度等级} \quad C &= 10 \\ \text{混凝土重力密度} \quad \gamma_3 &= 24 \quad \text{kN/m}^3 \end{aligned}$$

二、设计计算

(一)截面尺寸拟定 (见图L-01)

$$\begin{aligned} \text{顶板、底板厚度} \quad \delta &= 0.7 \quad \text{m} \\ C_1 &= 0.25 \quad \text{m} \\ \text{侧墙厚度} \quad t &= 0.6 \quad \text{m} \\ C_2 &= 0.25 \quad \text{m} \\ \text{横梁计算跨径} \quad L_P = L_0 + t &= 6.6 \quad \text{m} \\ L = L_0 + 2t &= 7.2 \quad \text{m} \\ \text{侧墙计算高度} \quad h_P = h_0 + \delta &= 4.7 \quad \text{m} \\ h = h_0 + 2\delta &= 5.4 \quad \text{m} \\ \text{基础襟边} \quad c &= 0.2 \quad \text{m} \\ \text{基础高度} \quad d &= 0.1 \quad \text{m} \\ \text{基础宽度} \quad B &= 7.6 \quad \text{m} \end{aligned}$$

(二)荷载计算

1、恒载

$$\text{恒载竖向压力} \quad p_{\text{恒}} = \gamma_1 H + \gamma_2 \delta = 123.70 \quad \text{kN/m}^2$$

恒载水平压力

$$\text{顶板处} \quad e_{P1} = \gamma_1 H \tan^2(45^\circ - \Phi/2) = 35.40 \quad \text{kN/m}^2$$

$$\text{底板处} \quad e_{P2} = \gamma_1 (H+h) \tan^2(45^\circ - \Phi/3) = 67.80 \quad \text{kN/m}^2$$

2、活载

汽车后轮着地宽度0.6m, 由《公路桥涵设计通用规范》(JTG D60—2004)第4.3.4条规定, 按30°角向下分布。

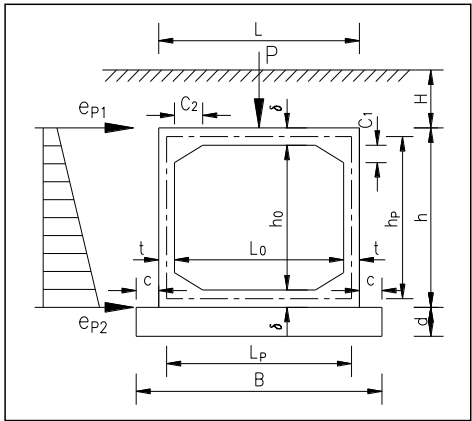


图 L-01

一个汽车后轮横向分布宽

$$\begin{aligned} 0.6/2 + H \tan 30^\circ &= 3.71 \text{ m} > 1.3/2 \text{ m} \\ &> 1.8/2 \text{ m} \end{aligned}$$

故横向分布宽度

$$a = (0.6/2 + H \tan 30^\circ) \times 2 + 1.3 = 8.713 \text{ m}$$

同理，纵向，汽车后轮着地长度0.2m

$$0.2/2 + H \tan 30^\circ = 3.506 \text{ m} > 1.4/2 \text{ m}$$

故

$$b = (0.2/2 + H \tan 30^\circ) \times 2 = 7.013 \text{ m}$$

$$\Sigma G = 140 \text{ kN}$$

$$\text{车辆荷载垂直压力 } q_{\text{车}} = \Sigma G / (a \times b) = 2.29 \text{ kN/m}^2$$

$$\text{车辆荷载水平压力 } e_{\text{车}} = q_{\text{车}} \tan^2(45^\circ - \varphi/2) = 0.76 \text{ kN/m}^2$$

(三)内力计算

1、构件刚度比

$$K = (I_1/I_2) \times (h_p/L_p) = 1.13$$

2、节点弯矩和轴向力计算

(1)a种荷载作用下 (图L-02)

$$\text{涵洞四角节点弯矩 } M_{aA} = M_{aB} = M_{aC} = M_{aD} = -1/(K+1) \cdot pL_p^2/12$$

$$\text{横梁内法向力 } N_{a1} = N_{a2} = 0$$

$$\text{侧墙内法向力 } N_{a3} = N_{a4} = pL_p/2$$

$$\text{恒载 } p = p_{\text{恒}} = 123.70 \text{ kN/m}^2$$

$$M_{aA} = M_{aB} = M_{aC} = M_{aD} = -210.73 \text{ kN} \cdot \text{m}$$

$$N_{a3} = N_{a4} = 408.21 \text{ kN}$$

$$\text{车辆荷载 } p = q_{\text{车}} = 2.29 \text{ kN/m}^2$$

$$M_{aA} = M_{aB} = M_{aC} = M_{aD} = -3.90 \text{ kN} \cdot \text{m}$$

$$N_{a3} = N_{a4} = 7.56 \text{ kN}$$

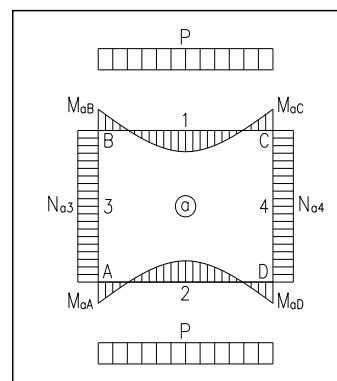


图 L-02

(2)b种荷载作用下 (图L-03)

$$M_{bA} = M_{bB} = M_{bC} = M_{bD} = -K/(K+1) \cdot ph_p^2/12$$

$$N_{b1} = N_{b2} = ph_p/2$$

$$N_{b3} = N_{b4} = 0$$

$$\text{恒载 } p = e_{P1} = 35.40 \text{ kN/m}^2$$

$$M_{bA} = M_{bB} = M_{bC} = M_{bD} = -34.58 \text{ kN} \cdot \text{m}$$

$$N_{b1} = N_{b2} = 83.19 \text{ kN}$$

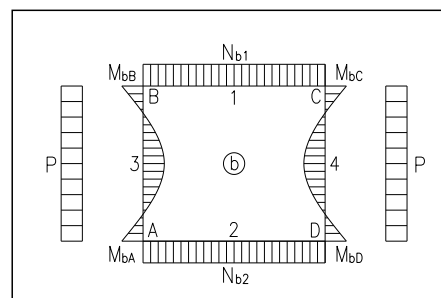


图 L-03

(3)c种荷载作用下 (图L-04)

$$M_{cA} = M_{cD} = -K(3K+8)/[(K+1)(K+3)] \cdot ph_p^2/60$$

$$M_{cB} = M_{cC} = -K(2K+7)/[(K+1)(K+3)] \cdot ph_p^2/60$$

$$N_{c1} = ph_p/6 + (M_{cA} - M_{cB})/h_p$$

$$N_{c2} = ph_p/3 - (M_{cA} - M_{cB})/h_p$$

$$N_{c3} = N_{c4} = 0$$

$$\text{恒载 } p = e_{P2} - e_{P1} = 32.40 \text{ kN/m}^2$$

$$M_{cA} = M_{cD} = -17.46 \text{ kN} \cdot \text{m}$$

$$M_{cB} = M_{cC} = -14.19 \text{ kN} \cdot \text{m}$$

$$N_{c1} = 24.69 \text{ kN}$$

$$N_{c2} = 51.45 \text{ kN}$$

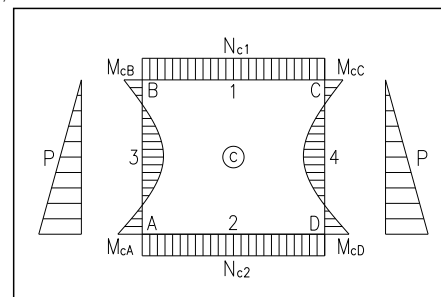


图 L-04

(4)d种荷载作用下 (图L-05)

$$M_{dA} = -[K(K+3)/6(K^2+4K+3) + (10K+2)/(15K+5)] \cdot ph_p^2/4$$

$$M_{dB} = -[K(K+3)/6(K^2+4K+3) - (5K+3)/(15K+5)] \cdot ph_p^2/4$$

$$M_{dC} = -[K(K+3)/6(K^2+4K+3) + (5K+3)/(15K+5)] \cdot ph_p^2/4$$

$$M_{dD} = -[K(K+3)/6(K^2+4K+3) - (10K+2)/(15K+5)] \cdot ph_p^2/4$$

$$N_{d1} = (M_{dD} - M_{dC})/h_p$$

$$N_{d2} = ph_p - (M_{dD} - M_{dC})/h_p$$

$$N_{d3} = -N_{d4} = -(M_{dB} - M_{dC})/L_p$$

$$p = e_{\text{车}} = 0.76 \quad \text{kN/m}^2$$

$$M_{dA} = -2.93 \quad \text{kN} \cdot \text{m}$$

$$M_{dB} = 1.29 \quad \text{kN} \cdot \text{m}$$

$$M_{dC} = -2.04 \quad \text{kN} \cdot \text{m}$$

$$M_{dD} = 2.18 \quad \text{kN} \cdot \text{m}$$

$$N_{d1} = 0.90 \quad \text{kN}$$

$$N_{d2} = 2.69 \quad \text{kN}$$

$$N_{d3} = -N_{d4} = -0.50 \quad \text{kN}$$

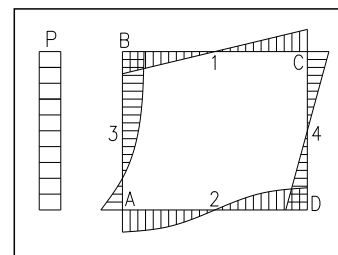


图 L-05

车辆荷载

(5) 节点弯矩、轴力计算及荷载效应组合汇总表

按《公路桥涵设计通用规范》(JTG D60—2004)第4.1.6条进行承载力极限状态效应组合

荷载种类		M (kN·m)				N (kN)			
		M _A	M _B	M _C	M _D	N ₁	N ₂	N ₃	N ₄
恒载	a	-210.73	-210.73	-210.73	-210.73	0	0	408.21	408.21
	1.2 × ∑ 结构、土的重力	-252.88	-252.88	-252.88	-252.88	0	0	489.85	489.85
	b	-34.58	-34.58	-34.58	-34.58	83.19	83.19	0	0
	c	-17.46	-14.19	-14.19	-17.46	24.69	51.45	0	0
	1.4 × ∑ 土侧压力	-72.86	-68.29	-68.29	-72.86	151.03	188.50	0	0
车辆荷载	a	-3.90	-3.90	-3.90	-3.90	0	0	7.56	7.56
	d	-2.93	1.29	-2.04	2.18	0.90	2.69	-0.50	0.50
	1.4 × ∑ 汽车	-9.57	-3.66	-8.31	-2.41	1.26	3.77	9.88	11.29
荷载效应组合		-335.30	-324.83	-329.48	-328.15	152.28	192.27	499.73	501.14

3、构件内力计算(跨中截面内力)

(1) 顶板 (图L-06)

$$x = L_p/2$$

$$P = 1.2p_{\text{恒}} + 1.4q_{\text{车}} = 151.65 \quad \text{kN}$$

$$N_x = N_1 = 152.28 \quad \text{kN}$$

$$M_x = M_B + N_3x - Px^2/2 = 498.57 \quad \text{kN} \cdot \text{m}$$

$$V_x = Px - N_3 = 0.71 \quad \text{kN}$$

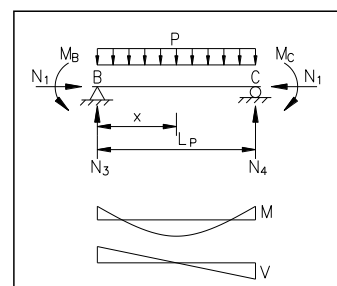


图 L-06

(2) 底板 (图L-07)

$$\omega_1 = 1.2p_{\text{恒}} + 1.4(q_{\text{车}} - 3e_{\text{车}}H_p^2/L_p^2)$$

$$= 150.02 \quad \text{kN/m}^2$$

$$\omega_2 = 1.2p_{\text{恒}} + 1.4(q_{\text{车}} + 3e_{\text{车}}H_p^2/L_p^2)$$

$$= 153.27 \quad \text{kN/m}^2$$

$$x = L_p/2$$

$$N_x = N_3 = 499.73 \quad \text{kN}$$

$$M_x = M_A + N_3x - \omega_1 \cdot x^2/2 - x^3(\omega_2 - \omega_1)/6L_p$$

$$= 494.00 \quad \text{kN} \cdot \text{m}$$

$$V_x = \omega_1x + x^2(\omega_2 - \omega_1)/2L_p - N_3$$

$$= -1.98 \quad \text{kN}$$

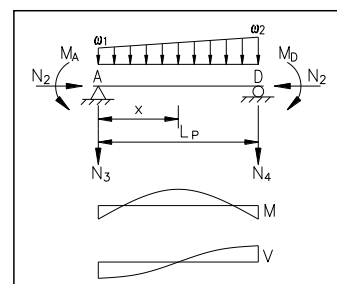


图 L-07

(3) 左侧墙 (图L-08)

$$\begin{aligned}
 \omega_1 &= 1.4e_{p1} + 1.4e_{\frac{h}{2}} \\
 &= 50.63 \quad \text{kN/m}^2 \\
 \omega_2 &= 1.4e_{p2} + 1.4e_{\frac{h}{2}} \\
 &= 95.99 \quad \text{kN/m}^2 \\
 x &= h_p/2 \\
 N_x = N_3 &= 499.73 \quad \text{kN} \\
 M_x &= M_B + N_1 x - \omega_1 \cdot x^2/2 - x^3(\omega_2 - \omega_1)/6h_p \\
 &= -127.64 \quad \text{kN} \cdot \text{m} \\
 V_x &= \omega_1 x + x^2(\omega_2 - \omega_1)/2h_p - N_1 \\
 &= -6.65 \quad \text{kN}
 \end{aligned}$$

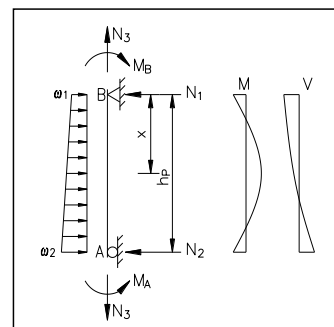


图 L-08

(4) 右侧墙 (图L-09)

$$\begin{aligned}
 \omega_1 &= 1.4e_{p1} = 49.56 \quad \text{kN/m}^2 \\
 \omega_2 &= 1.4e_{p2} = 94.92 \quad \text{kN/m}^2 \\
 x &= h_p/2 \\
 N_x = N_4 &= 501.14 \quad \text{kN} \\
 M_x &= M_C + N_1 x - \omega_1 \cdot x^2/2 - x^3(\omega_2 - \omega_1)/6h_p \\
 &= -129.34 \quad \text{kN} \cdot \text{m} \\
 V_x &= \omega_1 x + x^2(\omega_2 - \omega_1)/2h_p - N_1 \\
 &= -9.17 \quad \text{kN}
 \end{aligned}$$

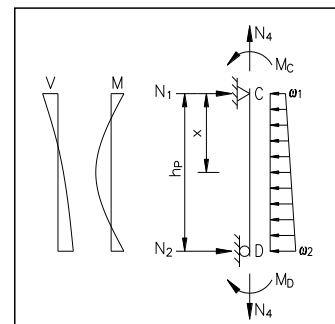


图 L-09

(5) 构件内力汇总表

构件	M _d	N _d	V _d	M _d	N _d	V _d	M _d	N _d	V _d
B - C	B			B-C			C		
	-324.83	152.28	499.73	498.57	152.28	0.71	-329.48	152.28	501.14
A - D	A			A-D			D		
	-335.30	192.27	499.73	494.00	192.27	-1.98	-328.15	192.27	501.14
B - A	B			B-A			A		
	-324.83	499.73	152.28	-127.64	499.73	-6.65	-335.30	499.73	192.27
C - D	C			C-D			D		
	-329.48	501.14	152.28	-129.34	501.14	-9.17	-328.15	501.14	192.27

(四) 截面设计

1、顶板 (B-C)

钢筋按左、右对称，用最不利荷载计算。

(1) 跨中

$$\begin{aligned}
 l_0 &= 6.60 \text{ m}, & h &= 0.70 \text{ m}, & a &= 0.03 \text{ m}, & h_0 &= 0.67 \text{ m}, & b &= 1.00 \text{ m}, \\
 M_d &= 498.57 \text{ kN} \cdot \text{m}, & N_d &= 152.28 \text{ kN}, & V_d &= 0.71 \text{ kN}
 \end{aligned}$$

$$e_0 = M_d/N_d = 3.274 \text{ m}$$

$$i = h/12^{1/2} = 0.202 \text{ m}$$

长细比

$$l_0/i = 32.66 > 17.5$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.10条

$$\xi_1 = 0.2 + 2.7e_0/h_0 = 13.394 > 1.0, \quad \text{取} \xi_1 = 1.00$$

$$\xi_2 = 1.15 - 0.01l_0/h = 1.056 > 1.0, \quad \text{取} \xi_2 = 1.00$$

$$\eta = 1 + (l_0/h)^2 \xi_1 \xi_2 h_0/1400e_0$$

$$\eta = 1.013$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.5条

$$e = \eta e_0 + h/2 - a = 3.637 \text{ m}$$

$$r_0 N_d e = f_{cd} b x (h_0 - x/2)$$

$$553.78 = 16100x(0.67 - x/2)$$

$$\text{解得} \quad x = 0.053 \text{ m} \leq \xi_b h_0 = 0.53 \times 0.67 = 0.355 \text{ m}$$

故为大偏心受压构件。

$$A_s = (f_{cd} b x - r_0 N_d) / f_{sd} = 0.0019684 \text{ m}^2 = 1968.4 \text{ mm}^2$$

$$\mu = 100 A_s / (b h_0) = 0.29 \% > 0.2 \%$$

符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第9.1.12条的要求。

选用 $\Phi 25 @ 240 \text{ mm}$, 实际 $A_s = 2045.3 \text{ mm}^2$

$$0.51 \times 10^{-3} f_{cu,k}^{1/2} b h_0 = 2021.5 \text{ kN} > r_0 V_d = 0.7 \text{ kN}$$

故抗剪截面符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.9条的要求。

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.10条

$$0.50 \times 10^{-3} \alpha_2 f_{td} b h_0 = 509.2 \text{ kN} > r_0 V_d = 0.7 \text{ kN}$$

故可不进行斜截面抗剪承载力的验算, 仅需按(JTG D62—2004)第9.3.13条构造要求配置箍筋。

(2) 结点

$$l_0 = 6.60 \text{ m} , \quad h = \delta + C_1 = 0.95 \text{ m} , \quad a = 0.03 \text{ m} , \quad h_0 = 0.92 \text{ m} , \quad b = 1.00 \text{ m} ,$$

$$M_d = 329.48 \text{ kN} \cdot \text{m} , \quad N_d = 152.28 \text{ kN} , \quad V_d = 501.14 \text{ kN}$$

$$e_0 = M_d / N_d = 2.164 \text{ m}$$

$$i = h / 12^{1/2} = 0.274 \text{ m}$$

$$\text{长细比} \quad l_0 / i = 24.07 > 17.5$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.10条

$$\xi_1 = 0.2 + 2.7 e_0 / h_0 = 6.550 > 1.0 , \quad \text{取} \xi_1 = 1.00$$

$$\xi_2 = 1.15 - 0.01 l_0 / h = 1.081 > 1.0 , \quad \text{取} \xi_2 = 1.00$$

$$\eta = 1 + (l_0 / h)^2 \xi_1 \xi_2 h_0 / 1400 e_0$$

$$\eta = 1.015$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.5条

$$e = \eta e_0 + h/2 - a = 2.640 \text{ m}$$

$$r_0 N_d e = f_{cd} b x (h_0 - x/2)$$

$$402.07 = 16100x(0.92 - x/2)$$

$$\text{解得} \quad x = 0.028 \text{ m} \leq \xi_b h_0 = 0.53 \times 0.92 = 0.488 \text{ m}$$

故为大偏心受压构件。

$$A_s = (f_{cd} b x - r_0 N_d) / f_{sd} = 0.0008094 \text{ m}^2 = 809.4 \text{ mm}^2$$

$$\mu = 100 A_s / (b h_0) = 0.09 \% < 0.2 \%$$

应按最小配筋率配置受拉钢筋。

选用 $\Phi 25 @ 260 \text{ mm}$, 实际 $A_s = 1888.0 \text{ mm}^2$

$$0.51 \times 10^{-3} f_{cu,k}^{1/2} b h_0 = 2775.8 \text{ kN} > r_0 V_d = 501.1 \text{ kN}$$

故抗剪截面符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.9条的要求。

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.10条

$$0.50 \times 10^{-3} \alpha_2 f_{td} b h_0 = 699.2 \text{ kN} > r_0 V_d = 501.1 \text{ kN}$$

故可不进行斜截面抗剪承载力的验算, 仅需按(JTG D62—2004)第9.3.13条构造要求配置箍筋。

2、底板 (A-D)

钢筋按左、右对称, 用最不利荷载计算。

(1) 跨中

$$l_0 = 6.60 \text{ m} , \quad h = 0.70 \text{ m} , \quad a = 0.03 \text{ m} , \quad h_0 = 0.67 \text{ m} , \quad b = 1.00 \text{ m} ,$$

$$M_d = 494.00 \text{ kN} \cdot \text{m} , \quad N_d = 192.27 \text{ kN} , \quad V_d = 1.98 \text{ kN}$$

$$e_0 = M_d / N_d = 2.569 \text{ m}$$

$$i = h / 12^{1/2} = 0.202 \text{ m}$$

$$\text{长细比} \quad l_0/i = 32.66 > 17.5$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.10条

$$\begin{aligned} \xi_1 &= 0.2 + 2.7e_0/h_0 = 10.554 > 1.0, & \text{取} \xi_1 &= 1.00 \\ \xi_2 &= 1.15 - 0.01l_0/h = 1.056 > 1.0, & \text{取} \xi_2 &= 1.00 \\ \eta &= 1 + (l_0/h)^2 \xi_1 \xi_2 h_0 / 1400e_0 \\ \eta &= 1.017 \end{aligned}$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.5条

$$\begin{aligned} e &= \eta e_0 + h/2 - a = 2.932 \text{ m} \\ r_0 N_d e &= f_{cd} b x (h_0 - x/2) \end{aligned}$$

$$563.71 = 16100x(0.67 - x/2)$$

$$\text{解得} \quad x = 0.054 \text{ m} \leq \xi_b h_0 = 0.53 \times 0.67 = 0.355 \text{ m}$$

故为大偏心受压构件。

$$\begin{aligned} A_s &= (f_{cd} b x - r_0 N_d) / f_{sd} = 0.001902 \text{ m}^2 = 1902.0 \text{ mm}^2 \\ \mu &= 100A_s / (bh_0) = 0.28 \% > 0.2 \% \end{aligned}$$

符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第9.1.12条的要求。

选用 $\Phi 25 @ 250 \text{ mm}$, 实际 $A_s = 1963.5 \text{ mm}^2$

$$0.51 \times 10^{-3} f_{cu,k}^{1/2} b h_0 = 2021.5 \text{ kN} > r_0 V_d = 2.0 \text{ kN}$$

故抗剪截面符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.9条的要求。

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.10条

$$0.50 \times 10^{-3} \alpha_2 f_{td} b h_0 = 509.2 \text{ kN} > r_0 V_d = 2.0 \text{ kN}$$

故可不进行斜截面抗剪承载力的验算, 仅需按(JTG D62—2004)第9.3.13条构造要求配置箍筋。

(2) 结点

$$\begin{aligned} l_0 &= 6.60 \text{ m}, & h &= \delta + C_1 = 0.95 \text{ m}, & a &= 0.03 \text{ m}, & h_0 &= 0.92 \text{ m}, & b &= 1.00 \text{ m}, \\ M_d &= 335.30 \text{ kN} \cdot \text{m}, & N_d &= 192.27 \text{ kN}, & V_d &= 499.73 \text{ kN} \\ e_0 &= M_d / N_d = 1.744 \text{ m} \\ i &= h / 12^{1/2} = 0.274 \text{ m} \end{aligned}$$

$$\text{长细比} \quad l_0/i = 24.07 > 17.5$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.10条

$$\begin{aligned} \xi_1 &= 0.2 + 2.7e_0/h_0 = 5.318 > 1.0, & \text{取} \xi_1 &= 1.00 \\ \xi_2 &= 1.15 - 0.01l_0/h = 1.081 > 1.0, & \text{取} \xi_2 &= 1.00 \\ \eta &= 1 + (l_0/h)^2 \xi_1 \xi_2 h_0 / 1400e_0 \\ \eta &= 1.018 \end{aligned}$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.3.5条

$$\begin{aligned} e &= \eta e_0 + h/2 - a = 2.221 \text{ m} \\ r_0 N_d e &= f_{cd} b x (h_0 - x/2) \end{aligned}$$

$$426.96 = 16100x(0.92 - x/2)$$

$$\text{解得} \quad x = 0.029 \text{ m} \leq \xi_b h_0 = 0.53 \times 0.92 = 0.488 \text{ m}$$

故为大偏心受压构件。

$$\begin{aligned} A_s &= (f_{cd} b x - r_0 N_d) / f_{sd} = 0.0007759 \text{ m}^2 = 775.9 \text{ mm}^2 \\ \mu &= 100A_s / (bh_0) = 0.08 \% < 0.2 \% \end{aligned}$$

应按最小配筋率配置受拉钢筋。

选用 $\Phi 25 @ 260 \text{ mm}$, 实际 $A_s = 1888.0 \text{ mm}^2$

$$0.51 \times 10^{-3} f_{cu,k}^{1/2} b h_0 = 2775.8 \text{ kN} > r_0 V_d = 499.7 \text{ kN}$$

故抗剪截面符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.9条的要求。

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.10条

$$0.50 \times 10^{-3} \alpha_2 f_{td} b h_0 = 699.2 \text{ kN} > r_0 V_d = 499.7 \text{ kN}$$

故可不进行斜截面抗剪承载力的验算，仅需按(JTG D62—2004)第9.3.13条构造要求配置箍筋。

3、左、右侧板 (B-A, C-D)

(1)板中

$$l_0 = 4.70 \text{ m}, \quad h = 0.60 \text{ m}, \quad a = 0.03 \text{ m}, \quad h_0 = 0.57 \text{ m}, \quad b = 1.00 \text{ m},$$

$$M_d = 129.34 \text{ kN} \cdot \text{m}, \quad N_d = 501.14 \text{ kN}, \quad V_d = 9.17 \text{ kN}$$

$$e_0 = M_d/N_d = 0.258 \text{ m}$$

$$i = h/12^{1/2} = 0.173 \text{ m}$$

$$\text{长细比} \quad l_0/i = 27.14 > 17.5$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTJ D62—2004)第5.3.10条

$$\xi_1 = 0.2 + 2.7e_0/h_0 = 1.423 > 1.0, \quad \text{取} \xi_1 = 1.00$$

$$\xi_2 = 1.15 - 0.01l_0/h = 1.072 > 1.0, \quad \text{取} \xi_2 = 1.00$$

$$\eta = 1 + (l_0/h)^2 \xi_1 \xi_2 h_0 / 1400 e_0$$

$$\eta = 1.097$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTJ D62—2004)第5.3.5条

$$e = \eta e_0 + h/2 - a = 0.553 \text{ m}$$

$$r_0 N_d e = f_{cd} b x (h_0 - x/2)$$

$$277.17 = 16100 x (0.57 - x/2)$$

$$\text{解得} \quad x = 0.031 \text{ m} \leq \xi_b h_0 = 0.53 \times 0.57 = 0.302 \text{ m}$$

故为大偏心受压构件。

$$A_s = (f_{cd} b x - r_0 N_d) / f_{sd} = -3.53 \times 10^{-6} \text{ m}^2 \quad \Rightarrow \quad 3.5 \text{ mm}^2$$

$$\mu = 100 A_s / (b h_0) = 0.00 \% < 0.2 \%$$

应按最小配筋率配置受拉钢筋。

选用 $\Phi 25 @ 430 \text{ mm}$, 实际 $A_s = 1141.6 \text{ mm}^2$

$$0.51 \times 10^{-3} f_{cu,k}^{1/2} b h_0 = 1719.8 \text{ kN} > r_0 V_d = 9.2 \text{ kN}$$

故抗剪截面符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTJ D62—2004)第5.2.9条的要求。

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTJ D62—2004)第5.2.10条

$$0.50 \times 10^{-3} \alpha_2 f_{td} b h_0 = 433.2 \text{ kN} > r_0 V_d = 9.2 \text{ kN}$$

故可不进行斜截面抗剪承载力的验算，仅需按(JTG D62—2004)第9.3.13条构造要求配置箍筋。

(2)结点

$$l_0 = 4.70 \text{ m}, \quad h = t + C_2 = 0.85 \text{ m}, \quad a = 0.03 \text{ m}, \quad h_0 = 0.82 \text{ m}, \quad b = 1.00 \text{ m},$$

$$M_d = 335.30 \text{ kN} \cdot \text{m}, \quad N_d = 499.73 \text{ kN}, \quad V_d = 192.27 \text{ kN}$$

$$e_0 = M_d/N_d = 0.671 \text{ m}$$

$$i = h/12^{1/2} = 0.245 \text{ m}$$

$$\text{长细比} \quad l_0/i = 19.15 > 17.5$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTJ D62—2004)第5.3.10条

$$\xi_1 = 0.2 + 2.7e_0/h_0 = 2.409 > 1.0, \quad \text{取} \xi_1 = 1.00$$

$$\xi_2 = 1.15 - 0.01l_0/h = 1.095 > 1.0, \quad \text{取} \xi_2 = 1.00$$

$$\eta = 1 + (l_0/h)^2 \xi_1 \xi_2 h_0 / 1400 e_0$$

$$\eta = 1.027$$

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTJ D62—2004)第5.3.5条

$$e = \eta e_0 + h/2 - a = 1.084 \text{ m}$$

$$r_0 N_d e = f_{cd} b x (h_0 - x/2)$$

$$541.65 = 16100 x (0.82 - x/2)$$

$$\text{解得} \quad x = 0.042 \text{ m} \leq \xi_b h_0 = 0.53 \times 0.82 = 0.435 \text{ m}$$

故为大偏心受压构件。

$$A_s = (f_{cd} b x - r_0 N_d) / f_{sd} = 0.000495 \text{ m}^2 = 495.0 \text{ mm}^2$$

$$\mu = 100A_s / (bh_0) = 0.06 \% < 0.2 \%$$

应按最小配筋率配置受拉钢筋。

选用 $\Phi 25 @ 290 \text{ mm}$, 实际 $A_s = 1692.7 \text{ mm}^2$

$$0.51 \times 10^{-3} f_{cu,k}^{1/2} b h_0 = 2474.1 \text{ kN} > r_0 V_d = 192.3 \text{ kN}$$

故抗剪截面符合《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.9条的要求。

由《公路钢筋混凝土及预应力混凝土桥涵设计规范》(JTG D62—2004)第5.2.10条

$$0.50 \times 10^{-3} \alpha_2 f_{td} b h_0 = 623.2 \text{ kN} > r_0 V_d = 192.3 \text{ kN}$$

故可不进行斜截面抗剪承载力的验算, 仅需按(JTG D62—2004)第9.3.13条构造要求配置箍筋。

(五) 配筋图

见设计图纸。

(六) 基底应力验算

1、荷载计算 (取单位涵长计算)

(1) 恒载

$$\text{箱重力} \quad P_{\text{箱}} = 2 \gamma_2 (\delta L + t h_0 + C_1 C_2) = 375.1 \text{ kN}$$

$$\text{基础重力} \quad P_{\text{基}} = \gamma_3 B d = 18.2 \text{ kN}$$

$$\text{填土重力} \quad P_{\text{土}} = \gamma_1 H L = 764.6 \text{ kN}$$

$$\text{水重力} \quad P_{\text{水}} = \gamma_{\text{水}} (L_0 h_0 - 2 C_1 C_2) = 238.8 \text{ kN}$$

(2) 车辆荷载 (由图L-07)

$$\text{竖直力} \quad P_{\text{车}} = q_{\text{车}} L = 16.5 \text{ kN}$$

$$\text{水平力} \quad E_{\text{车}} = e_{\text{车}} (h+d) = 4.2 \text{ kN}$$

$$\text{弯矩} \quad M_{\text{车}} = E_{\text{车}} (h+d) / 2 = 11.6 \text{ kN} \cdot \text{m}$$

2、基底应力

$$N = P_{\text{箱}} + P_{\text{基}} + P_{\text{土}} + P_{\text{水}} + P_{\text{车}} = 1413.3 \text{ kN}$$

$$M = M_{\text{车}} = 11.6 \text{ kN} \cdot \text{m}$$

由《公路桥涵地基与基础设计规范》(JTJ 024—85)第3.2.2-2式

$$\begin{aligned} \sigma &= N/A \pm M/W = N/B \pm 6M/B^2 \\ &= \frac{187.2}{184.8} \text{ kPa} < [\sigma_0] = 200 \text{ kPa} \end{aligned}$$

基底应力满足设计要求。