1

	Formula	Range
	$R_1 = 0.56197 + 0.9313\Phi_1 + 0.00065\Phi_2$ $\Phi_1 = \begin{cases} -0.043 + 0.452(A1) + 0.075(A1)^2 & \text{if } A1 \le -2 \\ 2.997 + 6.278(A1) + 4.122(A1)^2 + 0.964(A1)^3 & \text{if } A1 > -2 \end{cases}$ $\Phi_2 = \begin{cases} -1.461 - 4.460(A2) + 392.524(A2)^2 + 2955.995(A2)^3 + 4914.455(A2)^4 & \text{if } A2 \le 0 \\ -1.425 + 45.240(A2) - 309.329(A2)^2 + 832.054(A2)^3 - 765.888(A2)^4 & \text{if } A2 > 0 \end{cases}$ $A1 = -0.7919x1 + 0.60762x2 + 0.06072x3$ $A2 = 0.01799x1 - 0.88168x2 + 0.4715x3$ $X = [x1, x2, x3] = \left[\dfrac{s}{\}}, \dfrac{a}{\}}, \dfrac{s \times a}{\}^2}\right]$	$0.05 \le \dfrac{a}{\}} \le 0.4$ $0 \le \dfrac{s}{\}} \le 4.0$
	$R_1 = 0.58306 + 0.19316\Phi_1 + 0.06236\Phi_2$ $\Phi_1 = \begin{cases} 0.159 + 1.604(A1) + 0.820(A1)^2 + 0.135(A1)^3 & \text{if } (A1) \le -1 \\ 1.319 + 4.509(A1) + 1.760(A1)^2 - 0.914(A1)^3 & \text{if } (A1) > -1 \end{cases}$ $\Phi_2 = \begin{cases} 2.151 + 11.020(A2) - 2.894(A2)^2 & \text{if } (A2) \le -0.2 \\ 2.210 + 11.770(A2) - 16.209(A2)^2 - 70.589(A2) & \text{if } (A2) > -0.2 \end{cases}$ $A1 = -0.51308x1 + 0.85264x2 + 0.08604x3 - 0.04849x4$ $A2 = -0.07313x1 - 0.93937x2 + 0.33502x3 + 0.00055x4$ $X = [x1, x2, x3, x4] = \left[\dfrac{t}{\}}, \dfrac{a}{\}}, \dfrac{t \times a}{\}^2}, \dfrac{t}{a}\right]$	$0.1 \le \dfrac{a}{\}} \le 0.4$ $0 \le \dfrac{t}{\}} \le 1.6$
	$R_1 = 0.44485 + 0.17726\Phi_1 + 0.02072\Phi_2$ $\Phi_1 = \begin{cases} 0.230 + 1.078(A1) + 0.177(A1)^2 & \text{if } A1 \le -1 \\ 2.480 + 6.329(A1) + 3.363(A1)^2 & \text{if } A1 > -1 \end{cases}$ $\Phi_2 = \begin{cases} -1.754 + 11.049(A2) + 8.611(A2)^2 & \text{if } A2 \le 0.12 \\ -2.398 + 20.152(A2) - 15.813(A2)^2 & \text{if } A2 > 0.12 \end{cases}$ $A1 = -0.54456x1 + 0.83346x2 - 0.09349x3 - 0.00724x4$ $A2 = 0.05007x1 + 0.87037x2 - 0.48983x3 + 0.00362x4$ $X = [x1, x2, x3, x4] = \left[\dfrac{t}{\}}, \dfrac{a}{\}}, \dfrac{t \times a}{\}^2}, \dfrac{t}{a}\right]$	$0.05 \le \dfrac{a}{\}} \le 0.4$ $0 \le \dfrac{t}{\}} \le 3$
	$R_2 = 0.9399 + 0.07986\Phi_1$ $\Phi_1 = -4.0308 + \dfrac{1}{0.2029 + 0.0345 A1^{-3.3043}}$ $A1 = -0.9436\dfrac{a}{\}} + 0.3310\dfrac{L}{\}}$	$2 \le \dfrac{L}{\}} \le 7$ $0.05 \le \dfrac{a}{\}} \le 0.3$
	$R_2 = 1.00477 + 0.01214\Phi_1$ $\Phi_1 = -0.5344 + 1.654(1 - A1)^{-10.7412}$ $A1 = 0.9951\dfrac{a}{\}} - 0.09856\dfrac{W}{\}}$	$2 \le \dfrac{W}{\}} \le 7$ $0.05 \le \dfrac{a}{\}} \le 0.3$
[6]	$R_3 = \begin{cases} 0.99864 - 0.51237(x1) - 0.0672\}n(x2) + 0.00315\}n^2(x2) \\ \quad + 0.015936(x1)^2 * \}n^2(x2) \\ 1.04284 - 0.84692(x1) - 0.0009299\}n(x2) + 0.06837(x1)\}n(x2) \\ \quad + 0.63417(x1)^2 + 0.0042\}n^2(x2) - 0.000629(x1) * \}n(x2)^3 \quad \text{if } x1 > 5 \end{cases}$ $X = [x1, x2] = \left[\dfrac{a}{\}}, \dfrac{AGG}{k\}}\right]$	$0.05 \le \dfrac{a}{\}} \le 0.3$ $5 \le \dfrac{AGG}{k\}}$

$R_4 = 0.61711 + 0.15373\Phi_1 + 0.02504\Phi_2$ $\Phi_1 = \begin{cases} 0.693 + 1.279(A1) + 0.369(A1)^2 + 0.037(A1)^3 & \text{if } (A1) \le -2.5 \\ 2.839 + 8.234(A1) + 8.158(A1)^2 + 3.608(A1)^3 + 0.576(A1)^4 & \text{if } (A1) > -2.5 \end{cases}$ $\Phi_2 = \begin{cases} -2.285 + 5.921(A2) - 6.001(A2)^2 + 7.743(A2)^3 & \text{if } (A2) \le 0.5 \\ -3.008 + 4.693(A2) + 4.334(A2)^2 - 2.167(A2)^3 & \text{if } (A2) > 0.5 \end{cases}$ $A1 = -0.98868x1 - 0.12214x2 - 0.08717x3$ $A2 = 0.19802x1 + 0.98019x2 + 0.00305x3$ $X = [x1, x2, x3] = \left[\dfrac{D_0}{}, \dfrac{a}{}, \dfrac{D_0}{a}\right]$	$0.1 \le \dfrac{a}{} \le 0.4$ $0 \le \dfrac{D_0}{} \le 2$
$R_5 = 0.72692 + 0.14272\Phi_1 + 0.00933\Phi_2$ $\Phi_1 = \begin{cases} 3.31765 + 2.4036(A1) & \text{if } A1 \le -1.4 \\ 5.72684 + 4.10244(A1) & \text{if } A1 > -1.4 \end{cases}$ $\Phi_2 = \begin{cases} 14.535 - 20.351(A2) + 5.986(A2)^2 & \text{if } A2 \le 1.2 \\ 1.619 - 8.367(A2) + 4.877(A2)^2 & \text{if } A2 > 1.2 \end{cases}$ $A1 = 0.11914x1 - 0.99288x2$ $A2 = 0.65518x1 + 0.75547x2$ $h_{efft} = \sqrt{h_1^2 + \dfrac{E_2 h_2}{E_1 h_1} h_2^2}$, $X = [x1, x2] = \left[\dfrac{a}{}, \left(\dfrac{h_{efft}}{h1}\right)^2\right]$	$0.05 \le \dfrac{a}{} \le 0.4$ $1 \le \left(\dfrac{h_{efft}}{h_1}\right)^2 \le 2$
$r = \dfrac{(1/2)h_1(h_1 + h_2)}{h_1 + h_2(E_1/E_2)}$, $s = (1/2)(h_1 + h_2) - r$ $h_{1f} = \sqrt[3]{h_1^3 + 12h_1 s^2}$, $h_{2f} = \sqrt[3]{h_2^3 + 12h_2 s^2}$ $hefft = \sqrt{h_{1f}^2 + \left(\dfrac{h_{2f}}{h_{1f}}\right)h_{2f}^2}$, $X = [x1, x2] = \left[\dfrac{a}{}, \left(\dfrac{h_{efft}}{h_{1f}}\right)^2\right]$ R_5	( )
$R_T = 0.94825 + 0.15054\Phi_1(A1) + 0.03724\Phi_2(A2) + 0.03395\Phi_3(A3)$ $\Phi_1(A1) = \begin{cases} -2.5575 + 0.8003(A1) - 0.8003(A1)^2 & \text{if } A1 \le 3 \\ -2.6338 + 1.1038(A1) - 0.0914(A1)^2 & \text{if } 3 < A1 \le 7 \\ 0.7564 - 0.0155(A1) & \text{if } A1 > 7 \end{cases}$ $\Phi_2(ATX2) = \begin{cases} -0.6788 + 0.0.8003(A2) - 0.8003(A2)^2 & \text{if } A2 \le 3 \\ 3.7674 - 2.297(A2) + 0.2963(A2)^2 & \text{if } 3 < A2 \le 7 \\ -7.0337 + 1.2945(A2) & \text{if } A2 > 7 \end{cases}$ $\Phi_3(ATX3) = \begin{cases} 4.0843 + 4.8241(A3) & \text{if } A3 \le 3 \\ 0.1815 + 0.0541(A3) - 1.0899(A3)^2 & \text{if } -1 < A3 \le 0.5 \\ 0.0453 + 0.0383(A3) & \text{if } A3 > 0.5 \end{cases}$ $ATX1 = -0.04724X1 + 0.56954*X2 - 0.08408X3 + 0.20033X4 - 0.26647X5 + 0.00375X6 + 0.73881X7 - 0.01142X8 + 0.0953X9 + 0.01121X10$ $ATX2 = 0.03869X1 + 0.35781X2 + 0.09078X3 - 0.04054X4 + 0.86388X5 + 0.01635X6 - 0.31246X7 + 0.00552X8 - 0.12677X9 - 0.01765X10$ $ATX3 = 0.58567X1 + 0.25804X2 + 0.14784X3 + 0.14984X4 + 0.12743X5 - 0.05012X6 + 0.72295X7 - 0.0131X8 - 0.01304X9 - 0.06591X10$ $X = [x1, x2, x3, ..., x10]$ $= \left[\dfrac{W}{}, \dfrac{L}{}, ADT, \dfrac{a}{}, DG, DP, \dfrac{L}{}*\dfrac{a}{}, \dfrac{L}{}*ADT, DG*\dfrac{L}{}, DG*\dfrac{W}{}\right]$	$0.05 \le \dfrac{a}{} \le 0.3$ $3 \le \dfrac{W}{} \le 11$ $\dfrac{W}{} = \dfrac{L}{}$ $1.06 \le DG \le 9.93$ $2.61 \le DP \le 140.74$ $5.5 \le ADT \le 22$ $DG = dx \times 10^5$ $DP = dp \times 10^5$ $ADT = r \times \Delta T \times 10^6$

2 **(PCAPAV and TKUPAV)**

(A)	(kips)		PCAPAV (f_2=0.973, f_3=0.894, f_4=0.953)						TKUPAV (R_1=0.398, R_2=0.992, f_3=0.894, f_4=0.953)					σ_{eq} Ratio
Load	Load*1.2	n_i	$6*Me/h^2$	f1	σ_{eq}, psi (A)		N_i	n_i/N_i, (%)	σ_w, psi	σ_{eq}, psi (B)		N_i	n_i/N_i, (%)	(B/A)
30	36.0	6310	243.4	1.952	393.6	0.606	26536	23.8	1186.5	398.6	0.613	21414	29.5	1.01
28	33.6	14690	243.4	1.829	368.9	0.568	76395	19.2	1107.4	372.0	0.572	66751	22.0	1.01
26	31.2	30140	243.4	1.706	344.1	0.529	234343	12.9	1028.3	345.5	0.531	218058	13.8	1.00
24	28.8	64410	243.4	1.583	319.1	0.491	1218769	5.3	949.2	318.9	0.491	1243647	5.2	1.00
22	26.4	106900	243.4	1.458	294.1	0.452	41207557	0.3	870.1	292.3	0.450	Unlimited	0.0	0.99
20	24.0	235800	243.4	1.333	268.9	0.414	Unlimited	0.0	791.0	265.7	0.409	Unlimited	0.0	0.99
18	21.6	307200	243.4	1.208	243.5	0.375	Unlimited	0.0	711.9	239.2	0.368	Unlimited	0.0	0.98
16	19.2	422500	243.4	1.081	218.0	0.335	Unlimited	0.0	632.8	212.6	0.327	Unlimited	0.0	0.98
14	16.8	586900	243.4	0.954	192.3	0.296	Unlimited	0.0	553.7	186.0	0.286	Unlimited	0.0	0.97
12	14.4	1837000	243.4	0.825	166.3	0.256	Unlimited	0.0	474.6	159.4	0.245	Unlimited	0.0	0.96
							Subtotal=	61.4%				Subtotal=	70.5%	
(B)	(kips)		PCAPAV (f_2=0.973, f_3=0.894, f_4=0.953)						TKUPAV (R_1=0.180, R_2=0.992, f_3=0.894, f_4=0.953)					
52	62.4	21320	226.0	1.706	319.5	0.492	1177998	0.018	2056.6	312.2	0.480	2342697	0.9	0.98
48	57.6	42870	226.0	1.583	296.4	0.456	24134471	0.002	1898.4	288.2	0.443	Unlimited	0.0	0.97
44	52.8	124900	226.0	1.458	273.1	0.42	Unlimited	0.000	1740.2	264.2	0.406	Unlimited	0.0	0.97
40	48.0	372900	226.0	1.333	249.7	0.384	Unlimited	0.000	1582.0	240.2	0.370	Unlimited	0.0	0.96
36	43.2	885800	226.0	1.208	226.1	0.348	Unlimited	0.000	1423.8	216.2	0.333	Unlimited	0.0	0.96
32	38.4	930200	226.0	1.081	202.4	0.311	Unlimited	0.000	1265.6	192.1	0.296	Unlimited	0.0	0.95
28	33.6	1656000	226.0	0.954	178.6	0.275	Unlimited	0.000	1107.4	168.1	0.259	Unlimited	0.0	0.94
24	28.8	984900	226.0	0.825	154.5	0.238	Unlimited	0.000	949.2	144.1	0.222	Unlimited	0.0	0.93
20	24.0	1227000	226.0	0.695	130.1	0.2	Unlimited	0.000	791.0	120.1	0.185	Unlimited	0.0	0.92
16	19.2	1356000	226.0	0.563	105.5	0.162	Unlimited	0.000	632.8	96.1	0.148	Unlimited	0.0	0.91
							Subtotal=	2.0%				Subtotal=	0.9%	
							$\Sigma\, n_i/N_i$ =	63.4%				$\Sigma\, n_i/N_i$ =	71.4%	

3 TKUPAV   (σ_c=88.5 psi)

(A)	(kips)			90%				10%						
Load	Load*1.2	n_i	σ_{eq}, psi (A)	n_i*90%	N_i	(%)	R_T	σ_{eq}, psi		n_i*10%	N_i	(%)	(%)
30	36.0	6310	398.6	5679	21414	26.5	0.850	462.7	0.712	631	1382	45.7	72.2
28	33.6	14690	372.0	13221	66751	19.8	0.847	435.9	0.671	1469	4345	33.8	53.6
26	31.2	30140	345.5	27126	218058	12.4	0.845	409.1	0.629	3014	13654	22.1	34.5
24	28.8	64410	318.9	57969	1243647	4.7	0.842	382.4	0.588	6441	42899	15.0	19.7
22	26.4	106900	292.3	96210	Unlimited	0.0	0.840	355.6	0.547	10690	135064	7.9	7.9
20	24.0	235800	265.7	212220	Unlimited	0.0	0.838	328.9	0.506	23580	577713	4.1	4.1
18	21.6	307200	239.2	276480	Unlimited	0.0	0.836	302.1	0.465	30720	8444924	0.4	0.4
16	19.2	422500	212.6	380250	Unlimited	0.0	0.833	275.4	0.424	42250	Unlimited	0.0	0.0
14	16.8	586900	186.0	528210	Unlimited	0.0	0.831	248.7	0.383	58690	Unlimited	0.0	0.0
12	14.4	1837000	159.4	1653300	Unlimited	0.0	0.830	222.0	0.341	183700	Unlimited	0.0	0.0
					Subtotal=	63.4%					Subtotal=	128.9%	192.3%
(B)	(kips)												
52	62.4	21320	312.2	19188	2342697	0.8	0.853	376.5	0.579	2132	55171	3.9	4.7
48	57.6	42870	288.2	38583	Unlimited	0.0	0.869	353.7	0.544	4287	147221	2.9	2.9
44	52.8	124900	264.2	112410	Unlimited	0.0	0.874	330.1	0.508	12490	533733	2.3	2.3
40	48.0	372900	240.2	335610	Unlimited	0.0	0.868	305.6	0.470	37290	5139145	0.7	0.7
36	43.2	885800	216.2	797220	Unlimited	0.0	0.858	280.9	0.432	88580	Unlimited	0.0	0.0
32	38.4	930200	192.1	837180	Unlimited	0.0	0.853	256.4	0.394	93020	Unlimited	0.0	0.0
28	33.6	1656000	168.1	1490400	Unlimited	0.0	0.847	232.0	0.357	165600	Unlimited	0.0	0.0
24	28.8	984900	144.1	886410	Unlimited	0.0	0.842	207.6	0.319	98490	Unlimited	0.0	0.0
20	24.0	1227000	120.1	1104300	Unlimited	0.0	0.838	183.2	0.282	122700	Unlimited	0.0	0.0
16	19.2	1356000	96.1	1220400	Unlimited	0.0	0.833	158.9	0.244	135600	Unlimited	0.0	0.0
					Subtotal=	0.8%					Subtotal=	9.8%	10.7%
					$\Sigma\, n_i/N_i =$	64.2%					$\Sigma\, n_i/N_i =$	138.84%	203.0%