

INSTRUCTIONS:

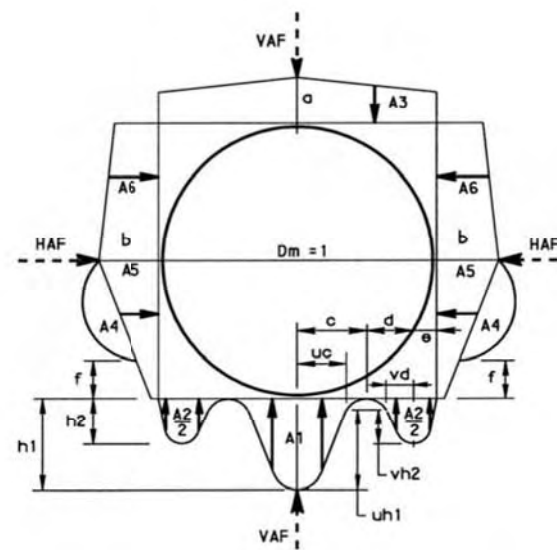
- FOR USAGE OF TYPE A OR TYPE B PIPE, REFER TO D.M. 2, TABLE 10.3.5
- FOR DIAMETERS GREATER THAN 1200 mm (48"), USE TYPE A DESIGN FILL HEIGHT TABLES.
- LOCAL AUTHORITIES MAY USE TYPE B OR TYPE A DESIGN FILL HEIGHT TABLES.
- SPECIFY SHORING/TRENCH BOX INSTALLATION IF REQUIRED BY SITE CONDITIONS.
- USE PAIDD COMPUTER PROGRAM TO PERFORM PIPE DESIGNS FOR REQUIRED FILL HEIGHTS AND CONCRETE STRENGTHS NOT SHOWN IN THE DESIGN TABLES (SHEETS 4 THRU 9 (10 THRU 16), OR AS INDICATED BY DOUBLE ASTERISKS (**)).
- REFER TO SHEET 3 FOR ADDITIONAL INSTRUCTIONS FOR USAGE OF THIS STANDARD.

DEFINITIONS:

- DIA = INSIDE DIAMETER OF THE CONCRETE PIPE IN MILLIMETERS (INCHES).
- TYPE A STANDARD INSTALLATION = HEAVY-DUTY CONCRETE PIPE EMBANKMENT INSTALLATION DESIGN (APPROXIMATELY 100-YEAR LIFE).
- TYPE A SHORING/TRENCH BOX INSTALLATION = HEAVY-DUTY CONCRETE PIPE TRENCH BOX OR SHORING INSTALLATION DESIGN (APPROXIMATELY 100-YEAR LIFE).
- TYPE B STANDARD INSTALLATION = STANDARD DUTY CONCRETE PIPE EMBANKMENT INSTALLATION DESIGN (APPROXIMATELY 50-YEAR LIFE).
- TYPE B SHORING/TRENCH BOX INSTALLATION = STANDARD DUTY CONCRETE PIPE TRENCH BOX OR SHORING INSTALLATION DESIGN (APPROXIMATELY 50-YEAR LIFE).
- PROOF TEST LOAD = THREE EDGE BEARING TEST TO A LOAD EXTRAPOLATED FROM 178 μ m (0.007") DESIGN REQUIREMENT TO PRODUCE A 254 μ m (0.01") CRACK.
- PROOF LOAD = THE LOAD CARRIED BY A PIPE SUBJECTED TO A THREE EDGE BEARING TEST, EXPRESSED IN KILONEWTONS PER METER (POUNDS PER LINEAR FOOT) OF INSIDE DIAMETER. THE PROOF LOAD REFLECTS THE FIELD SERVICE LOAD CONDITION FOR BOTH LIVE AND DEAD LOADS.
- PAIDD = PENNSYLVANIA INSTALLATION DIRECT DESIGN.
- H = DESIGN FILL HEIGHT mm (FEET).
- f_y = SPECIFIED YIELD STRENGTH OF REINFORCEMENT MPa (KSI)
- f'_c = SPECIFIED COMPRESSIVE STRENGTH OF CONCRETE MPa (KSI)
- HAF = HORIZONTAL ARCHING FACTOR
- VAF = VERTICAL ARCHING FACTOR
- D_m = 1 FOR UNITY
- A1 - A6 = COEFFICIENTS WHICH REPRESENT THE INTEGRATION OF NON-DIMENSIONAL VERTICAL AND HORIZONTAL COMPONENTS OF SOIL PRESSURE UNDER THE INDICATED PORTIONS OF THE COMPONENT PRESSURE DIAGRAMS (AREA UNDER COMPONENT PRESSURE DIAGRAMS).
- a, b, c, d, e, f, u, v = NON-DIMENSIONAL COEFFICIENTS DEFINING HORIZONTAL AND VERTICAL DIMENSIONS OF COMPONENT PRESSURE REGIONS.
- d = 0.5 - c - e
- $h_1 = \frac{(1.5a)}{c(1+u)}$
- $h_2 = \frac{(1.5A2)}{[(d)(1+v) + (2e)]}$
- SPAN RATIO = SPAN ELLIPTICAL/EQUIVALENT ROUND = 1.28
- RISE RATIO = RISE ELLIPTICAL/EQUIVALENT ROUND = 0.63
- VAF = VAF ROUND
- HAF = (RISE RATIO/SPAN RATIO) (HAF ROUND PIPE)
- = 0.49 (HAF ROUND PIPE)

PROCEDURE FOR EARTH LOAD MODELING:

CONSULT THE "CONCRETE PIPE TECHNOLOGY HANDBOOK", 1993 (PUBLISHED BY THE AMERICAN CONCRETE PIPE ASSOCIATION), CHAPTER 8, OR APPENDIX H OF THE DESIGN MANUAL PART 4, STRUCTURES, FOR A PROCEDURE FOR EARTH LOAD MODELING.



SOIL PRESSURE DISTRIBUTION MODEL

NOTES:

1. FOR SHEETS 1 THROUGH 10, ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED. FOR U.S. CUSTOMARY UNIT DETAILS, SEE SHEETS 11 THROUGH 18.
2. FABRICATE CONCRETE PIPE AS PER PUBLICATION 280M (PUB. 280) ENTITLED "PENNSYLVANIA INSTALLATION DIRECT DESIGN MANUFACTURING SPECIFICATION".
3. SEE RC-30M AND PUBLICATION 408, SECTIONS 601 AND 604 FOR INSTALLATION OF CONCRETE PIPES.
4. DESIGN CONCRETE PIPE IN ACCORDANCE WITH PENNSYLVANIA INSTALLATION DIRECT DESIGN (PAIDD), AND APPENDIX H OF DESIGN MANUAL, PART 4, STRUCTURES.
5. TEST CONCRETE PIPES IN ACCORDANCE WITH PUBLICATION 408 AND PROOF TEST LOAD TABLES (PRESENTED IN THIS STANDARD AND IN PUBLICATION 280M (280)). PROOF TEST LOADS INCLUDE A 1.43 FACTOR OF SAFETY FOR FIELD CRACKING. TESTING TO ULTIMATE IS NOT REQUIRED.
6. REFERENCE RC-30M FOR MINIMUM FILL HEIGHT AND COVER REQUIREMENTS FOR CONCRETE PIPES.
7. THE DESIGN VALUES SHOWN IN THIS STANDARD ARE BASED UPON THE ASSUMPTION THAT THE EXCAVATION, BACKFILL AND CONSTRUCTION METHODS IN THE RC STANDARDS AND PUBLICATION 408 ARE USED.
8. ELLIPTICAL REINFORCEMENT IS NOT PERMITTED, EXCEPT FOR QUADRANT REINFORCEMENT AND FOR REINFORCEMENT OF ELLIPTICAL PIPE.
9. SMOOTH WELDED WIRE FABRIC IS USED IN THE DESIGN OF THE STEEL AREAS FOR CONCRETE PIPE. USE OF DEFORMED WIRE FABRIC OR DEFORMED WIRE IS PERMITTED.
10. USE DESIGN TABLES GIVEN IN THIS STANDARD TO DETERMINE STEEL AREA. USE PAIDD SOFTWARE FOR DESIGNS NOT COVERED BY THESE TABLES.
11. STEEL AREAS SHOWN ARE IN mm^2/m ($IN.^2/FT.$).
12. PROVIDE ADDITIONAL CONCRETE COVER FOR ACIDIC ($pH \leq 4$) OR ABRASIVE ENVIRONMENTS.
13. ENSURE THAT CONSTRUCTION CONDITIONS (SHALLOW FILLS AND CONSTRUCTION TRAFFIC, IF APPLICABLE) ARE CONSIDERED AT THE TIME THE PIPE IS SPECIFIED.
14. A 600 mm (2 FT.) SPACING IS REQUIRED (A 1000 mm (3 FT.) SPACING IS PREFERRED) FOR MULTIPLE PIPES [SEE PAIDD SPECIFICATIONS FOR SKETCH].
15. PIPE MAY NOT BE PLACED WITHIN THE PAVEMENT STRUCTURE WITHOUT CHIEF BRIDGE ENGINEER APPROVAL.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF DESIGN

STANDARD
REINFORCED CONCRETE PIPES
DESIGN CRITERIA

RC-30M	SUBSURFACE DRAINS - PIPE PLACEMENT EXCAVATION - BEDDING - BACKFILL	RECOMMENDED 6-9-10 J. Ross P. Meecore CHIEF BRIDGE ENGINEER	RECOMMENDED 6-9-10 Bureau of Design DIRECTOR, BUREAU OF DESIGN	SHEET 1 OF 18 BD-636M
REFERENCE DRAWINGS				

TABLE A

DESIGN DATA				
ITEMS	STANDARD INSTALLATION		TRENCH BOX/SHORING INSTALLATION	
	TYPE A	TYPE B	TYPE A	TYPE B
INSTALLATION TYPE	PAIDD	PAIDD	PAIDD	PAIDD
HAUNCH COMPACTION	95% MIN.	95% MIN.	60% MIN.	60% MIN.
SOIL WEIGHT	2250 kg/m ³	2250 kg/m ³	2250 kg/m ³	2250 kg/m ³
LIVE LOAD	HS 25	HS 25	HS 25	HS 25
f _y	450 MPa	450 MPa	450 MPa	450 MPa
f'c	MIN. 28 MPa	MIN. 28 MPa	MIN. 28 MPa	MIN. 28 MPa
CONCRETE COVER	25 mm OVER STEEL	25 mm OVER STEEL	25 mm OVER STEEL	25 mm OVER STEEL
LOAD FACTORS				
	TYPE A	TYPE B	TYPE A	TYPE B
DEAD LOAD & EARTH LOAD FACTOR (SHEAR & MOMENT)	1.30	1.30	1.30	1.30
DEAD LOAD FACTOR (THRUST) REINFORCEMENT DESIGN CONCRETE COMPRESSION	1.00	1.00	1.00	1.00
LIVE LOAD FACTOR (SHEAR & MOMENT)	2.17	2.17	2.17	2.17
LIVE LOAD FACTOR (THRUST)	1.00	1.00	1.00	1.00
INTERNAL PRESSURE LOAD FACTORS (THRUST)	1.50	1.50	1.50	1.50
IMPACT (TO 2500 mm HEIGHT)	40(1.0-0.0004H)>10%	40(1.0-0.0004H)>10%	40(1.0-0.0004H)>10%	40(1.0-0.0004H)>10%
STRENGTH REDUCTION FACTORS				
	TYPE A	TYPE B	TYPE A	TYPE B
FLEXURE	0.90	0.95	0.90	0.95
RADIAL TENSION	0.85	0.90	0.85	0.90
DIAGONAL TENSION	0.85	0.90	0.85	0.90
CRACK CONTROL FACTOR	0.7	0.7	0.7	0.7
ORIENTATION ANGLE	±10°	±10°	±10°	±10°
MATERIAL & PROCESS FACTORS				
	TYPE A	TYPE B	TYPE A	TYPE B
RADIAL TENSION	1.0	1.0	1.0	1.0
DIAGONAL TENSION	1.0	1.0	1.0	1.0
EMBANKMENT ARCHING FACTORS				
	TYPE A	TYPE B	TYPE A	TYPE B
VAF (VERTICAL)	1.35	1.35	SEE TABLE 'C'	SEE TABLE 'C'
HAF (HORIZONTAL)	0.45	0.45		

TABLE B

ARCHING COEFFICIENTS															
INSTALLATION TYPE	VAF	HAF	A1	A2	A3	A4	A5	A6	a	b	c	e	f	u	v
EMBANKMENT	1.35	0.45	0.62	0.73	1.35	0.19	0.08	0.18	1.40	0.40	0.18	0.08	0.05	0.80	0.80
TRENCH BOX OR SHORING	*	*	1.45	0.00	1.45	0.00	0.11	0.19	1.45	0.30	0.25	0.00	--	0.90	--

* SEE TABLE 'C'

TABLE C

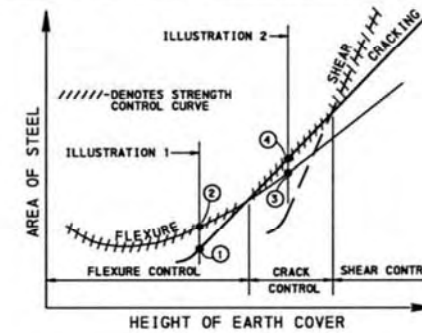
FACTORS FOR TRENCH BOX OR SHORING INSTALLATION*				
REQUIRED FILL HEIGHT millimeters	300 mm THROUGH 900 mm DIAMETER		1050 mm THROUGH 3000 mm DIAMETER	
	VAF	HAF	VAF	HAF
500	1.20	0.29	1.20	0.29
600	1.15	0.29	1.20	0.29
1000	1.00	0.25	1.20	0.25
2000	0.70	0.18	0.90	0.18
3000	0.70	0.16	0.90	0.16
4500 - 7500	0.70	0.12	0.80	0.12

* BEDDING FACTOR USED TO DETERMINE PROOF TEST LOAD 1.60 FOR EARTH LOADS. LIVE LOAD BEDDING FACTOR AS PER ACPA "DESIGN DATA 40" DECEMBER 1992.

TABLE D

FACTORS FOR TRENCH BOX OR SHORING INSTALLATION FOR ELLIPTICAL PIPE										
REQUIRED FILL HEIGHT millimeters	EQUIVALENT ROUND		HORIZONTAL ELLIPTICAL				VERTICAL ELLIPTICAL			
	VAF	HAF	VAF		HAF		VAF		HAF	
			300 TO 900	1050 TO 3000	300 TO 900	1050 TO 3000	300 TO 900	1050 TO 3000	300 TO 900	1050 TO 3000
500	1.20	0.29	1.20	1.20	0.18	0.18	1.20	1.20	0.46	0.46
600	1.10	0.22	1.15	1.20	0.18	0.18	1.15	1.20	0.46	0.46
1000	1.10	0.22	1.00	1.20	0.16	0.16	1.00	1.20	0.40	0.40
2000	0.90	0.16	0.70	0.90	0.10	0.1	0.70	0.90	0.29	0.29
3000	0.80	0.12	0.70	0.90	0.10	0.1	0.70	0.90	0.25	0.25
4500 - 7500			0.70	0.90	0.08	0.08	0.70	0.90	0.19	0.19

FLEXURE-SHEAR-CRACK CONTROL RELATIONSHIP



EXAMPLE: TYPE B 1200 mm (48") STANDARD INSTALLATION

	600<H<1000 (2'H<3')		1000<H<2000 (3'H<7')	
WALL THICKNESS	144	(5 3/4")	144	(5 3/4")
AREA OF STEEL	318	(0.15)	296	(0.14)
INNER CAGE	191	(0.09)	148	(0.07)
OUTER CAGE	8.6	(587)	12.0	(823)
PROOF TEST LOAD				

AS SEEN HERE, THE ACTUAL STRENGTH OF THE 1000 mm - 600 mm (3'-2") PIPE IS GREATER THAN THE 2000 mm - 1000 mm (7'-3") PIPE AS REFLECTED BY THE STEEL AREA. THE PROOF LOAD TEST BEING A SERVICE LOAD CONDITION REFLECTS THE ANTICIPATED FIELD LOAD. THE ULTIMATE STRENGTH DESIGN METHOD USED TO DETERMINE STEEL AREAS HAS GREATER DESIGN SAFETY FACTOR FOR LIVE LOADS THAN FOR DEAD LOADS. FOR THIS REASON, THE PROOF LOAD, FOR LOW FILL HEIGHTS, IS NOT A LINEAR RELATIONSHIP WITH THE STEEL AREA.

ILLUSTRATION 1:

1. CRACK CONTROL 2. FLEXURE CONTROL

IN THIS ILLUSTRATION OF THE FLEXURE-SHEAR-CRACK CONTROL RELATIONSHIP, THE PROOF TEST LOAD FOR THIS CASE IS NOT A GOVERNING FACTOR SINCE FLEXURE CONTROLS THE DESIGN.

ILLUSTRATION 2:

3. FLEXURE CONTROL 4. CRACK CONTROL

IN THIS ILLUSTRATION OF THE FLEXURE-SHEAR-CRACK CONTROL RELATIONSHIP, THE PROOF TEST LOAD FOR THIS CASE IS A GOVERNING FACTOR SINCE FLEXURE IS NOT CONTROLLING THE DESIGN.

NOTE: PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES, RELY UPON THE MAXIMUM/MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF DESIGN

STANDARD
REINFORCED CONCRETE PIPES
DESIGN CRITERIA

GENERAL NOTE:
SEE SHEET 10 FOR TABLES A, B, C, AND D
IN U.S. CUSTOMARY UNITS.

RECOMMENDED 6-9-10
Thos Mecore
CHIEF BRIDGE ENGINEER

RECOMMENDED 6-9-10
Burt Shyne
DIRECTOR, BUREAU OF DESIGN

SHEET 2 OF 18
BD-636M

REINFORCED CONCRETE PIPE DESIGN EXAMPLES:

① DESIGN OF A 1200 mm (48") DIAMETER CONCRETE PIPE UNDER 1000 mm (3'-0") OF FILL.

TYPE A (HEAVY-DUTY) SOLUTION:

- DESIGNER DETERMINES THAT A 1200 mm (48") DIAMETER PIPE IS REQUIRED AND THAT THE MAXIMUM FILL HEIGHT IS 1000 mm (3'-0"). END TREATMENT AND A STANDARD TYPE A INSTALLATION AS PER RC-30M ARE SPECIFIED.
- ITEM #0601-7072 IS SPECIFIED. FILL RANGE 3000 mm - 600 mm (10'-2').
- FABRICATOR REFERENCES PUBLICATION 280M (280) "PAIDD MANUFACTURING SPECIFICATION" FOR A 1200 mm (48") DIAMETER TYPE A STANDARD INSTALLATION PIPE. A 125 mm (5") WALL THICKNESS AND $f'c = 28 \text{ MPa}$ (4000 PSI) ARE SELECTED FOR 1200 mm (48") DIAMETER. THE AREA OF STEEL REQUIRED FOR A 1000 mm $\leq H < 2000$ mm (3' $\leq H < 7'$) MAXIMUM FILL HEIGHT IS 402 mm²/m (0.19 IN.²) FOR THE INSIDE CAGE AND 254 mm²/m (0.12 IN.²) FOR THE OUTER CAGE.
- THE PIPE IS TESTED TO A PROOF TEST LOAD OF 12.7 kN/m (867 LBS./LF) AND MARKED PA 1200A/S3000-600 (48A/S10-2).

TYPE B (STANDARD DUTY) SOLUTION:

- DESIGNER DETERMINES THAT A 1200 mm (48") DIAMETER CONCRETE PIPE IS REQUIRED AND THAT THE MAXIMUM FILL HEIGHT IS 1000 mm (3'-0") END TREATMENT AND A STANDARD TYPE B INSTALLATION AS PER RC-30M ARE SPECIFIED.
- ITEM #0601-7370 IS SPECIFIED. FILL RANGE 3000 mm - 1000 mm (10'-3').
- FABRICATOR REFERENCES PUBLICATION 280M (280) "PAIDD MANUFACTURING SPECIFICATION" FOR A 1200 mm (48") DIAMETER TYPE B STANDARD INSTALLATION PIPE. A 144 mm (5 3/4") WALL THICKNESS AND $f'c = 35 \text{ MPa}$ (5000 PSI) ARE SELECTED FOR 1200 mm (48") DIAMETER. THE AREA OF STEEL REQUIRED FOR A 1000 mm $\leq H < 3000$ mm (3' $\leq H < 7'$) MAXIMUM FILL HEIGHT IS 296 mm²/m (0.14 IN.²) FOR THE INSIDE CAGE AND 148 mm²/m (0.07 IN.²) FOR THE OUTER CAGE.
- THE PIPE IS TESTED TO A PROOF TEST LOAD OF 12.0 kN/m (823 LBS./LF) AND MARKED PA 1200B/S3000-1000 (48B/S10-3).

② DESIGN OF A 900 mm (36") DIAMETER CONCRETE PIPE UNDER 2700 mm (9') OF FILL IN A TRENCH BOX INSTALLATION. SOLUTION:

- DESIGNER DETERMINES THAT A 900 mm (36") DIAMETER PIPE IS REQUIRED AND MAXIMUM FILL HEIGHT IS 2700 mm (9'-0"). END TREATMENT AND A TYPE A TRENCH BOX INSTALLATION AS PER RC-30M ARE SPECIFIED.
- ITEM #0601-7537 IS SPECIFIED. FILL RANGE 3000 mm - 2000 mm (10'-7").
- FABRICATOR REFERENCES PUBLICATION 280M (280) "PAIDD MANUFACTURING SPECIFICATION" FOR A 900 mm (36") DIAMETER TYPE A SHORING/TRENCH BOX INSTALLATION PIPE. A DOUBLE CAGE, 100 mm (4") WALL THICKNESS AND $f'c = 28 \text{ MPa}$ (4000 PSI) ARE SELECTED FOR A 900 mm (36") DIAMETER. THE AREA OF STEEL REQUIRED FOR A 2000 mm $\leq H < 3000$ mm (7' $\leq H < 10'$) MAXIMUM FILL HEIGHT IS 339 mm²/m (0.16 IN.²) FOR THE INSIDE CAGE AND 148 mm²/m (0.07 IN.²) FOR THE OUTER CAGE.
- THE PIPE IS TESTED TO A PROOF TEST LOAD OF 17.1 kN/m (1174 LBS./LF) AND MARKED PA 900A/SH3000-2000 (36A/SH10-7).

③ SELECTION OF NON-STANDARD ITEM FOR A PA825A/SH 3M - 0.5M

- THE DESIGNER DETERMINES THAT A PA825A/SH 3M - 0.5M IS REQUIRED. THE ITEM NUMBERS AVAILABLE IN THE CONSTRUCTION ITEMS CATALOG ARE AS FOLLOWS:

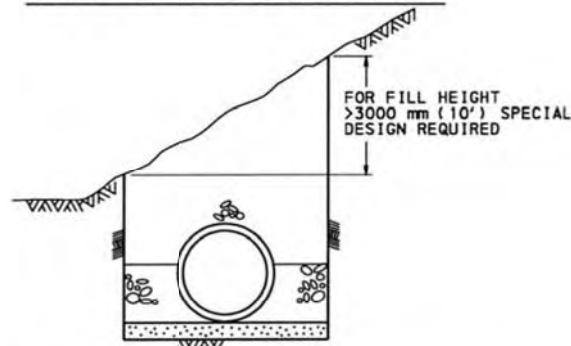
2601-0529 M 825mm REINFORCED SHORE/TRENCH BOX CONCRETE PIPE TYPE A	0.6M-0.5M
2601-0530 M 825mm REINFORCED SHORE/TRENCH BOX CONCRETE PIPE TYPE A	1M - 0.6M
2601-0531 M 825mm REINFORCED SHORE/TRENCH BOX CONCRETE PIPE TYPE A	2M - 1M
2601-0532 M 825mm REINFORCED SHORE/TRENCH BOX CONCRETE PIPE TYPE A	3M - 2M
2601-0533 M 825mm REINFORCED SHORE/TRENCH BOX CONCRETE PIPE TYPE A	4.5M - 1M

- NOTE THAT NO STANDARD ITEM NUMBER ENCOMPASSES THE 3M TO 0.5M FILL REQUIRED FOR THE PIPE.

GO TO THE APPROPRIATE BD-636M FILL HEIGHT TABLE FOR TYPE A SHORING INSTALLATION FOR A CIRCULAR PIPE. USING THE 825mm PIPE DIAMETER, 94mm WALL THICKNESS, AND 28M PA CONCRETE STRENGTH, NOTE THE STEEL AREA FOR THE MINIMUM FILL HEIGHT: HERE, 762mm²/M. ALSO, NOTE THE STEEL AREA FOR THE MAXIMUM FILL HEIGHT: HERE, 487mm²/M. SELECT THE LARGER REQUIRED STEEL AREA (762mm²/M), AND THE ITEM NUMBER THAT CONTAINS THE GREATER STEEL AREA - 2501 - 0529M 825mm REINFORCED SHORE TRENCH BOX CONCRETE PIPE TYPE A 0.6M - 0.5M.

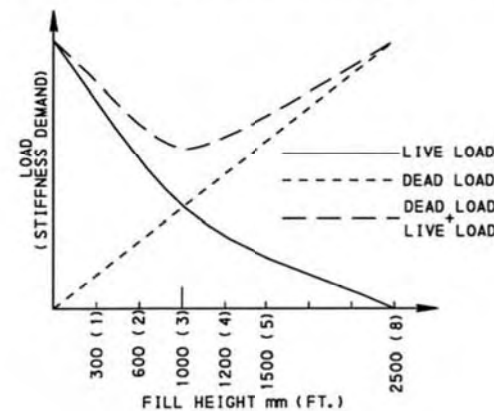
- ON THE TAB SHEET INDICATE THE ACTUAL MAXIMUM AND MINIMUM FILLS OF 3M AND 0.5M (NOT THE FILL RANGE PER THE ITEM NUMBER). IN THE REMARKS SECTION INDICATE, "THE STEEL AREA FOR THE PIPE SPECIFIED SATISFIES THE FILL HEIGHT RANGE 4.50M TO 0.5M".

SIDE SLOPE CONDITION



SYMMETRICAL REINFORCEMENT IS REQUIRED FOR INSTALLATIONS WHERE SIDE SLOPE CONDITIONS EXIST. A SPECIAL DESIGN IS REQUIRED WHEN THE FILL HEIGHT VARIES MORE THAN 3000 mm (10') OVER THE TRENCH WIDTH.

CONCRETE PIPE LOADING CURVE



FOR SUBSTITUTION OF PIPES UNDER 1000 mm (3'-0") OF FILL OR LESS USE A LOWER HEIGHT OF FILL. FOR SUBSTITUTION OF PIPES OVER 1000 mm (3'-0") OF FILL OR GREATER, USE A HIGHER HEIGHT OF FILL.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

RESPONSIBILITIES FOR DESIGN, FABRICATION AND INSTALLATION OF CONCRETE PIPES

DESIGNER:

- DETERMINES DIAMETER OF PIPE REQUIRED BY HYDRAULICS.
- DETERMINES MAXIMUM HEIGHT OF FILL. - FOR LONG PIPE RUNS, THE LENGTH MAY BE DIVIDED INTO SEGMENTS (DEPENDING UPON INLET LOCATIONS) WHICH MAY HAVE DIFFERENT MAXIMUM FILL HEIGHTS. - CONSIDERS THE EFFECT OF FUTURE WIDENING AND LOADS FOR THE PIPE DESIGN.
- ENSURES THAT THE SIDE SLOPE IS STABLE AND THAT THE PIPE IS NOT EXPECTED TO PROVIDE SLOPE STABILITY.
- SPECIFY CONCRETE PIPES AS INDICATED IN PUB. 280M (280), SECTION 17.1.2. FOR PIPES WITH I.D. ≥ 2500 mm (8') PREPARE S-DRAWINGS WHICH INCLUDE 2 CORE BORINGS AND A HEADWALL DESIGN ON THE DRAWING.
- SPECIFIES END TREATMENTS AS PER RC-30M.
- SPECIFIES INCREASED WALL THICKNESS, IF WARRANTED FOR ACIDIC OR ABRASIVE CONDITIONS.
- SPECIFIES TRENCH BOX/SHORING INSTALLATION IF REQUIRED.
- SPECIFIES PROPER ITEM NUMBER.

CONTRACTOR:

- SELECTS THE TYPE OF PIPE INSTALLATION, I.E., EMBANKMENT OR TRENCH BOX/SHORING.
- SUBMITS SPECIAL DESIGNS TO THE MATERIALS & TESTING DIVISION OF PENNDOT.
- INSTALLS THE PIPE AS PER RC-30M.

FABRICATOR:

- USES PRE-APPROVED DESIGNS [PAIDD/BD-636M, TABLES ON SHEETS 4 THRU 9 (11 THRU 16)] UNLESS A SPECIAL DESIGN IS REQUIRED.
- ENSURES THAT THE PROPER STRUCTURE DESIGN FOR THE PIPE IS SELECTED, TESTED AND DELIVERED.
- PROVIDES DESIGN AND DETAILS FOR SPECIAL DESIGN PIPES.
- CONDUCTS PROOF LOAD TESTS ACCORDING TO PUB. 280M (280) TO PROOF TEST LOAD VALUES SPECIFIED IN PUB. 280M (280) OR BD-636M.

PENNDOT MATERIALS AND TESTING DIVISION:

- WITNESSES PROOF LOAD TESTS, CONDUCTS Q/A AT FABRICATION SHOP, AND APPROVES/REJECTS PIPES AT THE PLANT PRIOR TO LOADING THE PIPES FOR TRANSPORTATION TO THE JOB SITE.
- APPROVES DESIGNS WHICH MEET THIS STANDARD OR PAIDD.
- PROVIDES SPECIAL DESIGNS TO THE BRIDGE QUALITY ASSURANCE DIVISION FOR APPROVAL.
- MONITORS CONCRETE STRENGTHS AND OTHER MATERIAL PROPERTIES. ENSURES THAT ONLY APPROVED [SPECIFIED IN PA MATERIALS SPECIFICATION PUB 280M (280)] SHEAR REINFORCEMENT IS USED.
- APPROVES SHOP DETAILS, ETC.
- COORDINATES EFFORTS TO RESOLVE PIPE FAILURE/PROBLEMS.

DISTRICT CONSTRUCTION UNIT:

- INSPECTS PIPE PRIOR TO INSTALLATION.
- MONITORS INSTALLATION, ENSURING ALL STEPS IN RC-30M AND PUB. 408 ARE FOLLOWED.
- INSPECTS PIPE AFTER THE SPECIFIED FILL IS PLACED.
- ACCEPTS PIPES IN ACCORDANCE WITH PUB. 408.

BUREAU OF DESIGN:

- MAINTAINS AND UPDATES THIS STANDARD, RC-30M, SPECIAL PROVISIONS, PUB. 408 AND PAIDD THROUGH PENNSYLVANIA CONCRETE PIPE ASSOCIATION.
- REVIEWS AND APPROVES SPECIAL DESIGNS SUBMITTED BY THE MATERIALS AND TESTING DIVISION.
- ASSISTS THE BUREAU OF CONSTRUCTION AND DISTRICTS IN RESOLUTION OF STRUCTURAL PROBLEMS.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF DESIGN

STANDARD
REINFORCED CONCRETE PIPES
DESIGN EXAMPLES/
RESPONSIBILITIES

TYPE A STANDARD INSTALLATION - STEEL AREAS (mm ² /m)														
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)											
			H=500	500 ≤ H<1000	600 ≤ H<2000	1000 ≤ H<2000	2000 ≤ H<3000	4500	6000	7500	9000	12 000	15 000	H>15 000
300	50	28	190	169								296	**	**
		35											381	**
300	69	28	169	169								191	233	**
375	57	28	254	169							212	254	466	**
375	75	28	169	169							169	191	254	402
450	63	28	296	191	169						233	275	339	**
		35											487	**
450	82	28	296	169	148						169	212	254	381
525	69	28	465	254	169	212	275	360	466	**	**	**	**	**
		41											550	**
525	88	28	212	148	169	212	275	339	572	**	**	**	**	**
		35	466											**
600	75	28	318	212	254	339	423	593	**	**	**	**	**	**
		35	465											**
600	94	28	275	169	212	275	339	402	720	**	**	**	**	**
675	82	28	360	254	212	212	296	402	508	**	**	**	**	**
		35											593	**
		41	571											**
675	100	28	318	212	191	191	254	318	402	487	**	**	**	**
		41	571											**
750	88	28	423	296	254	254	360	466	614	**	**	**	**	**
750	107	28	360	254	212	212	296	381	487	614	**	**	**	**
825	94	28	466	360	360	360	466	529	**	**	**	**	**	**
		35							656	889	**	**	**	**
825	113	28	402	318	254	254	339	445	550	741	**	**	**	**
900	100	28	508	402	296	339	466	614	**	**	**	**	**	**
		35							741	**	**	**	**	**
		41							**	953	**	**	**	**
900	119	28	423	360	275	296	402	508	635	**	**	**	**	**
		35							741	**	**	**	**	**

TYPE A STANDARD INSTALLATION - STEEL AREAS (mm ² /m)														
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)											
			H=500	500 ≤ H<1000	600 ≤ H<2000	1000 ≤ H<2000	2000 ≤ H<3000	4500	6000	7500	9000	12 000	H>12 000	
900	100	28	402	381	296	233	254	339	445	593	826	**	**	**
		41	275	254	191	148	148	169	233	296	360	**	**	**
		35											1101	**
900	119	28	339	318	254	212	212	275	360	445	529	1059	**	**
		35	212	191	148	148	148	169	212	254	360	**	**	**
1050	113	28	423	402	360	360	360	423	529	762	1037	**	**	**
		35	275	254	212	148	148	212	212	360	445	**	**	**
1050	132	28	339	339	296	296	296	339	445	529	783	**	**	**
		35	212	212	169	148	148	169	212	254	318	**	**	**
		41											1122	**
1200	125	28	381	423	402	487	656	953	1313	**	**	**	**	**
		35	232	275	254	254	339	423	508	**	**	**	**	**
1200	144	28	381	360	339	423	529	677	1101	**	**	**	**	**
		35	232	212	212	148	254	318	381	**	**	**	**	**
		41											1503	**
1350	138	28	445	445	423	550	804	1164	**	**	**	**	**	**
		35	296	275	254	296	381	487	**	**	**	**	**	**
		41											1355	**
1350	157	28	402	381	381	487	614	953	1440	**	**	**	**	**
		35	254	233	212	233	256	381	466	**	**	**	**	**


TYPE A STANDARD INSTALLATION - STEEL AREAS (mm ² /m)														
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)											
			H=500	500 ≤ H<1000	600 ≤ H<2000	1000 ≤ H<2000	2000 ≤ H<3000	4500	6000	7500	9000	H>9 000		
1500	150	28	466	466	466	466	466	635	953	1461	**	**	**	**
		35	296	275	275	254	254	339	445	550	**	**	**	**
1500	169	28	423	423	402	402	423	550	699	1249	**	**	**	**
		35	254	233	233	212	212	275	360	445	**	**	**	**
1650	163	28	508	487	487	529	741	1122	**	**	**	**	**	**
		35	296	296	296	381	487	**	**	**	**	**	**	**
		41											1397	**
1650	182	28	445	445	487	635	910	1503	**	**	**	**	**	**
		35	254	254	233	318	402	508	**	**	**	**	**	**
1800	175	28	529	529	508	550	614	847	1376	**	**	**	**	**
		35	318	318	296	296	318	423	550	**	**	**	**	**
		41											1609	**
1800	194	28	487	487	466	508	550	720	1122	1820	**	**	**	**
		35	275	275	254	254	275	360	466	572	**	**	**	**
		41											1524	**
1950	188	28	550	550	550	614	677	995	1651	**	**	**	**	**
		35	318	318	318	318	360	466	593	**	**	**	**	**
		41											1694	**
1950	207	28	508	508	508	572	614	804	1397	**	**	**	**	**
		35	296	275	275	275	296	402	508	**	**	**	**	**
		41											614	**
		41											1821	**
		35											720	**

TYPE A STANDARD INSTALLATION - STEEL AREAS (mm ² /m)														
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)											
			H=500	500 ≤ H<1000	600 ≤ H<2000	1000 ≤ H<2000	2000 ≤ H<3000	4500	6000	7500	H>7500			
2100	200	28	593	593	614	677	741	1143	1926	**	**	**	**	**
		41	339	339	339	339	381	508	656	**	**	**	**	**
		35											1905	**
2100	219	28	550	550	572	635	699	910	1672	**	**	**	**	**
		35	296	296	296	318	339	445	572	**	**	**	**	**
		41											1905	**
2250	213	28	635	635	677	762	826	1355	**	**	**	**	**	**
		35	360	360	360	402	423	572	**	**	**	**	**	**
		41							1694	**	**	**	**	**
2250	232	28	593	593	635	699	762	1101	1990	**	**	**	**	**
		41	318	318	318	360	381	487	635	**	**	**	**	**
		35											1736	**
2400	225	28	677	677	741	826	910	1567	**	**	**	**	**	**
		35	381	360	381	423	466	614	**	**	**	**	**	**
		41							1926	**	**	**	**	**
2400	244	28	635	635	699	783	847	1313	**	**	**	**	**	**
		35	339	339	360	381	423	550	**	**	**	**	**	**
		41							1672	**	**	**	**	**
		35							677	**	**	**	**	**
		41							2011	**	**	**	**	**
2550	238	28	720	741	804	910	1059	1821	**	**	**	**	**	**
		35	381	381	423	466	508	656	**	**	**	**	**	**
		41							2202	**	**	**	**	**
2550	257	28	677	699	762	847	931	1588	**	**	**	**	**	**
		35	360	360	381	423	466	593	**	**	**	**	**	**
		41							1948	**	**	**	**	**
		35							720	**	**	**	**	**
		41							1588	**	**	**	**	**
		35							720	**	**	**	**	**

TYPE A STANDARD INSTALLATION - STEEL AREAS (mm ² /m)														
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)											
			H=500	500 ≤ H<1000	600 ≤ H<2000	1000 ≤ H<2000	2000 ≤ H<3000	4500	6000	H>6000				
2700	250	28	762	783	868	974	1207	2117	**	**	**	**	**	**
		41	423	402	445	508	550	720	**	**	**	**	**	**
		35							2138	**	**	**	**	**
2700	269	28	741	741	826	931	1016	1884	**	**	**	**	**	**
		35	381	381	423	466	508	656	**	**	**	**	**	**
		41							2244	**	**	**	**	**
2850	267	28	826	847	931	1101	1355	**	**	**	**	**	**	**
		35	423	445	487	550	593	**	**	**	**	**	**	**
		41							1821	**	**	**	**	**
		35							762	**	**	**	**	**
		41							2328	**	**	**	**	**
2850	286	28	783	804	889	1016	1122	2181	**	**	**	**	**	**
		41	402	402	445									

TYPE A STANDARD INSTALLATION REQUIRED FILL/COVER HEIGHT (mm) - PROOF TEST LOAD (kN/m)																																		
DIA. (mm)	REQUIRED FILL/COVER HEIGHT (mm) - PROOF TEST LOAD (kN/m)														DIA. (mm)	REQUIRED FILL/COVER HEIGHT (mm) - PROOF TEST LOAD (kN/m)																		
	300 ≤ H ≤ 500	500 ≤ H ≤ 600	600 ≤ H ≤ 1000	1000 ≤ H ≤ 2000	2000 ≤ H ≤ 3000	3000 ≤ H ≤ 4500	4500 ≤ H ≤ 6000	6000 ≤ H ≤ 7500	7500 ≤ H ≤ 9000	9000 ≤ H ≤ 12 000	12 000 ≤ H ≤ 15 000	15 000 ≤ H ≤ 18 000	18 000 ≤ H ≤ 21 000	21 000 ≤ H ≤ 24 000		24 000 ≤ H ≤ 27 000	27 000 ≤ H ≤ 30 000	300 ≤ H ≤ 500	500 ≤ H ≤ 600	600 ≤ H ≤ 1000	1000 ≤ H ≤ 2000	2000 ≤ H ≤ 3000	3000 ≤ H ≤ 4500	4500 ≤ H ≤ 6000	6000 ≤ H ≤ 7500	7500 ≤ H ≤ 9000	9000 ≤ H ≤ 12 000	12 000 ≤ H ≤ 15 000	15 000 ≤ H ≤ 18 000	18 000 ≤ H ≤ 21 000	21 000 ≤ H ≤ 24 000	24 000 ≤ H ≤ 27 000	27 000 ≤ H ≤ 30 000	
300	25.1	18.4	14.2	11.0	10.3	10.6	10.2	10.2	36.1	47.9	59.8	71.7	83.7	95.6	107.5	119.5	1500	8.8	11.8	14.8	17.8	20.8	23.8	26.8	29.8	32.8	35.8	38.8	41.8	44.8	47.8	50.8	53.8	
375	22.6	16.5	12.2	9.4	8.7	9.0	8.6	8.6	35.2	46.7	58.3	69.9	81.6	93.2	104.8	116.5	1650	8.1	11.1	14.1	17.1	20.1	23.1	26.1	29.1	32.1	35.1	38.1	41.1	44.1	47.1	50.1	53.1	
500	20.6	15.3	11.0	8.2	7.5	7.8	7.4	7.4	34.6	45.9	57.3	68.8	80.2	91.6	103.1	114.5	1800	7.2	10.3	13.3	16.3	19.3	22.3	25.3	28.3	31.3	34.3	37.3	40.3	43.3	46.3	49.3	52.3	
525	19.0	14.3	10.1	7.3	6.6	6.9	6.5	6.5	34.1	45.4	56.6	67.9	79.2	90.5	101.8	113.1	1950	6.4	9.5	12.5	15.5	18.5	21.5	24.5	27.5	30.5	33.5	36.5	39.5	42.5	45.5	48.5	51.5	54.5
600	17.8	13.6	9.4	6.6	5.9	6.2	5.8	5.8	35.4	47.1	58.7	70.5	82.2	93.9	105.6	117.3	2100	5.7	8.8	11.8	14.8	17.8	20.8	23.8	26.8	29.8	32.8	35.8	38.8	41.8	44.8	47.8	50.8	53.8
675	20.3	15.4	10.7	7.9	7.2	7.5	7.1	7.1	35.1	46.7	58.3	69.9	81.6	93.2	104.8	116.5	2250	5.2	8.3	11.3	14.3	17.3	20.3	23.3	26.3	29.3	32.3	35.3	38.3	41.3	44.3	47.3	50.3	53.3
750	19.0	14.6	10.2	7.4	6.7	7.0	6.6	6.6	34.9	46.4	58.0	69.5	81.1	92.6	104.2	115.8	2400	4.8	7.9	10.9	13.9	16.9	19.9	22.9	25.9	28.9	31.9	34.9	37.9	40.9	43.9	46.9	49.9	52.9
825	18.0	13.9	9.8	7.0	6.3	6.6	6.2	6.2	34.8	46.2	57.7	69.2	80.7	92.2	103.7	115.2	2550	5.0	8.1	11.1	14.1	17.1	20.1	23.1	26.1	29.1	32.1	35.1	38.1	41.1	44.1	47.1	50.1	53.1
900	16.0	13.4	9.6	6.8	6.1	6.4	6.0	6.0	35.5	47.1	58.8	70.6	82.3	94.0	105.8	117.5	2700	4.6	7.7	10.7	13.7	16.7	19.7	22.7	25.7	28.7	31.7	34.7	37.7	40.7	43.7	46.7	49.7	52.7
1050	14.2	13.7	9.6	6.8	6.1	6.4	6.0	6.0	35.2	46.8	58.4	70.1	81.8	93.4	105.1	116.8	2850	4.3	7.4	10.4	13.4	16.4	19.4	22.4	25.4	28.4	31.4	34.4	37.4	40.4	43.4	46.4	49.4	52.4
1200	11.6	12.7	8.4	5.6	4.9	5.2	4.8	4.8	35.0	46.6	58.2	69.8	81.4	93.0	104.6	116.2	3000	4.0	7.1	10.1	13.1	16.1	19.1	22.1	25.1	28.1	31.1	34.1	37.1	40.1	43.1	46.1	49.1	52.1
1350	10.3	12.6	8.2	5.4	4.7	5.0	4.6	4.6	34.9	46.4	57.9	69.5	81.1	92.6	104.2	115.8																		

NOTE: THESE PROOF LOADS INCLUDE A FACTOR OF SAFETY OF 1.43 FOR FIELD CRACK CONTROL.

LEGEND
 = FOR INFORMATION ONLY. PROOF LOAD TEST MUST BE PERFORMED TO THE MAXIMUM PROOF TEST LOAD FOR THE RANGE OF ITEM NUMBER.

PROOF TEST LOAD TABLE FOR CIRCULAR PIPES - TYPE A STANDARD INSTALLATION

NOTE: PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 2.

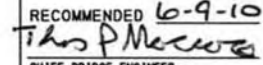
NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

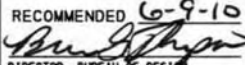
COMMONWEALTH OF PENNSYLVANIA
 DEPARTMENT OF TRANSPORTATION
 BUREAU OF DESIGN

STANDARD
 REINFORCED CONCRETE PIPES
 DESIGN TABLES

NOTE:

THESE PROOF LOADS INCLUDE A FACTOR OF SAFETY OF 1.43 FOR FIELD CRACK CONTROL. USE PAIDD PROGRAM TO DETERMINE PROOF LOAD VALUES FOR FILL HEIGHTS GREATER THAN 30 000 mm.

RECOMMENDED 6-9-10

 CHIEF BRIDGE ENGINEER

RECOMMENDED 6-9-10

 DIRECTOR, BUREAU OF DESIGN


SHEET 5 OF 18
 BD-636M

TYPE B STANDARD INSTALLATION - STEEL AREAS (mm ² /m)																	
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)														
			H ≤ 500	500 ≤ H ≤ 600	600 ≤ H ≤ 1000	1000 ≤ H ≤ 2000	2000 ≤ H ≤ 3000	4500	6000	7500	9000	12 000	15 000	H > 15 000			
300	50	28	190	*	*	*	*	*	*	*	*	*	*	*	254	**	**
		35	*	*	*	*	*	*	*	*	*	*	*	*	*	339	**
300	69	28	170	*	*	*	*	*	*	*	*	*	*	*	169	**	**
375	57	28	233	*	*	*	*	*	*	*	*	*	*	*	191	233	402
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	402
375	75	28	169	*	*	*	*	*	*	*	*	*	*	*	148	191	254
450	63	28	169	*	*	*	*	*	*	*	*	*	*	*	212	254	318
		35	*	*	*	*	*	*	*	*	*	*	*	*	*	445	**
450	82	28	275	*	*	*	*	*	*	*	*	*	*	*	169	212	233
525	69	28	254	233	148	*	*	*	*	*	*	*	*	*	191	254	339
525	88	28	360	148	148	148	148	148	148	148	148	148	148	148	191	254	318
600	75	28	465	296	212	212	212	212	212	212	212	212	212	212	233	318	402
600	94	28	465	254	169	169	169	169	169	169	169	169	169	169	191	254	318
675	82	28	339	233	212	212	212	212	212	212	212	212	212	212	275	381	466
		35	550	*	*	*	*	*	*	*	*	*	*	*	*	*	**
675	100	28	296	212	169	169	169	169	169	169	169	169	169	169	233	296	381
		35	529	*	*	*	*	*	*	*	*	*	*	*	*	*	**
750	88	28	381	275	275	275	275	275	275	275	275	275	275	275	339	445	550
		35	*	*	*	*	*	*	*	*	*	*	*	*	*	*	656
750	107	28	339	254	254	254	254	254	254	254	254	254	254	254	275	360	445
		41	572	*	*	*	*	*	*	*	*	*	*	*	*	*	**
825	94	28	445	339	339	339	339	339	339	339	339	339	339	339	381	508	656
		35	*	*	*	*	*	*	*	*	*	*	*	*	*	*	826
825	113	28	381	296	296	296	296	296	296	296	296	296	296	296	318	423	508
900	100	28	466	381	275	318	445	572	804	**	**	**	**	**	**	**	**
		35	*	*	*	*	*	*	*	*	*	*	*	*	*	*	995
900	119	28	402	339	254	275	381	487	593	**	**	**	**	**	**	**	**
		35	*	*	*	*	*	*	*	*	*	*	*	*	*	*	677
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	974
900	100	28	381	360	191	233	233	318	423	550	762	**	**	**	**	**	**
		35	254	233	148	148	148	148	148	148	148	148	148	148	148	148	1122
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	445
900	119	28	318	296	233	191	191	275	339	423	487	910	**	**	**	**	**
		35	191	191	148	148	148	148	148	148	148	148	148	148	148	148	148
1050	113	28	402	381	339	296	296	381	508	720	974	**	**	**	**	**	**
		41	254	254	191	169	169	212	275	339	402	**	**	**	**	**	**
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1313
1050	132	28	339	318	275	254	254	318	423	508	635	1291	**	**	**	**	**
		35	212	191	169	148	148	148	148	148	148	148	148	148	148	148	529
1200	125	28	402	402	381	339	339	445	614	889	1186	**	**	**	**	**	**
		41	254	254	233	191	191	233	318	402	487	**	**	**	**	**	**
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1567
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	614
1200	144	28	360	339	318	296	296	381	487	593	931	**	**	**	**	**	**
		35	212	212	191	148	148	191	233	296	360	**	**	**	**	**	**
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1313
		41	*	*	*	*	*	*	*	*	*	*	*	*	*	*	487

TYPE B STANDARD INSTALLATION REQUIRED FILL/COVER HEIGHT (mm) - PROOF TEST LOAD (KN/m)																
DIA. (mm)	300 ≤ H ≤ 500	500 ≤ H ≤ 600	600 ≤ H ≤ 1000	1000 ≤ H ≤ 2000	2000 ≤ H ≤ 3000	3000 ≤ H ≤ 4500	4500 ≤ H ≤ 6000	6000 ≤ H ≤ 7500	7500 ≤ H ≤ 9000	9000 ≤ H ≤ 12 000	12 000 ≤ H ≤ 15 000	15 000 ≤ H ≤ 18 000	18 000 ≤ H ≤ 21 000	21 000 ≤ H ≤ 24 000	24 000 ≤ H ≤ 27 000	27 000 ≤ H ≤ 30 000
300	23.9	11.2	13.5	10.4	2.6	11.7	23.1	28.7	34.3	45.5	56.8	68.2	79.5	90.8	102.2	113.5
375	21.5	15.7	12.8	9.8	12.3	11.3	22.5	27.9	33.4	44.4	55.4	65.0	77.5	88.5	99.6	110.7
450	19.6	14.5	11.7	9.7	12.1	17.0	22.1	27.5	32.8	43.6	54.5	65.3	76.2	87.0	97.9	108.8
525	18.1	13.6	11.1	8.5	11.9	16.7	21.9	27.1	32.4	43.1	53.8	64.5	75.2	86.0	96.7	107.4
600	16.9	12.9	10.6	9.8	12.3	17.3	22.7	28.1	33.6	44.7	55.8	66.9	78.1	89.2	100.3	111.5
675	19.3	14.7	10.1	9.6	12.2	17.2	22.5	27.9	33.4	44.4	55.4	66.4	77.5	88.5	99.6	110.7
750	18.1	13.9	9.7	9.5	12.1	17.1	22.4	27.8	33.2	44.1	55.1	66.0	77.0	88.0	99.0	110.0
825	17.1	13.2	9.3	9.5	12.0	17.0	22.3	27.6	33.0	43.9	54.8	65.7	76.6	87.6	98.5	109.4
900	15.2	12.7	9.1	9.6	12.2	17.3	22.7	28.2	33.7	44.8	55.9	67.0	78.2	89.3	100.5	111.7
1050	13.5	13.0	9.1	9.5	12.1	17.2	22.5	28.0	33.4	44.5	55.5	66.6	77.7	88.8	99.8	110.9
1200	11.0	12.1	8.6	9.4	12.0	17.1	22.4	27.8	33.3	44.3	55.3	66.3	77.3	88.3	99.4	110.4

NOTE:
THESE PROOF LOADS INCLUDE A 1.43
SAFETY FACTOR FOR FIELD CRACK CONTROL.

NOTE 1: PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 2.

LEGEND
 = FOR INFORMATION ONLY. PROOF LOAD TEST MUST BE PERFORMED TO THE MAXIMUM PROOF TEST LOAD FOR THE RANGE OF ITEM NUMBER.

- NOTES:
- 1) * INDICATES SAME STEEL AREA AS SHOWN FOR THE LESSER CONCRETE STRENGTH.
 - 2) ** INDICATES A SPECIAL DESIGN IS REQUIRED. USE PAIDD SOFTWARE.
 - 3) ELLIPTICAL REINFORCING IS NOT ALLOWED, EXCEPT FOR QUADRANT REINFORCEMENT AND FOR REINFORCEMENT OF ELLIPTICAL PIPE.
 - 4) FOR DOUBLE CAGE RINGS OF STEEL REINFORCED PIPE, TWO AREAS ARE SHOWN. THE GREATER AREA IS FOR THE INNER CAGE STEEL AND LESSER AREA IS FOR IS FOR OUTER CAGE STEEL.
 - 5) FOR PIPE SIZES GREATER THAN 1200 mm DIAMETER, USE TYPE A STANDARD INSTALLATION DESIGN TABLES.
 - 6) H = DESIGN FILL HEIGHT, mm.
 - 7) SUBSTITUTION OF PIPES UNDER FILLS OF 1000 mm OR LESS IS PERMITTED ONLY WITH DESIGNER APPROVAL.
 - 8) USE PAIDD SOFTWARE ONLY FOR PIPE DESIGNS NOT PROVIDED BY BD-636M.
 - 9) STEEL AREAS SPECIFIED IN THE FILL HEIGHT / STEEL AREA TABLES ARE TO BE ACHIEVED USING ONE LAYER OF REINFORCEMENT FOR EACH CAGE. TWO LAYERS MAY BE SUBSTITUTED FOR ONE LAYER PROVIDED THE SUM OF THE STEEL AREAS OF THE TWO LAYERS IS EQUAL TO THE AREA OF STEEL FOR THE SINGLE LAYER CAGE. WHEN SUBSTITUTING, SPACING OF REINFORCEMENT IS TO REMAIN THE SAME. DESIGNING FOR TWO LAYERS OF REINFORCEMENT AND PROVIDING ONE LAYER OF REINFORCEMENT OF EQUIVALENT AREA IS NOT PERMITTED.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

DESIGN TABLES AND PROOF TEST LOAD TABLE FOR CIRCULAR PIPES
- TYPE B STANDARD INSTALLATION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF DESIGN

**STANDARD
REINFORCED CONCRETE PIPES
DESIGN TABLES**

RECOMMENDED 6-9-10 <i>Thos P. Maciore</i> CHIEF BRIDGE ENGINEER	RECOMMENDED 6-9-10 <i>Bur...</i> DIRECTOR, BUREAU OF DESIGN	SHEET 6 OF 18 BD-636M
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TYPE A SHORING/TRENCH BOX - STEEL AREAS (mm ² /m)						
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)			
			H<500	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000
300	50	28				169
300	69	28				169
375	57	28				191
375	75	28				191
450	63	28				254
450	82	28				233
525	69	28				296
525	88	28				296
600	75	28				381
600	94	28				360
675	82	28				423
675	100	28				360
750	88	28	699	508	402	339
750	107	28	550	423	339	423
825	94	28	762	572	445	381
825	113	28	635	487	381	339
900	100	28	762	656	466	445
900	119	28	656	550	423	381
900	100	28	614	466	381	339
900	119	28	487	381	318	275
1050	113	28	635	550	487	487
1050	132	28	339	275	254	296
			508	466	423	423
			275	233	212	233

TYPE A SHORING/TRENCH BOX - STEEL AREAS (mm ² /m)						
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)			
			H<500	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000
1200	125	28	635	635	550	572
1200	144	28	339	339	275	275
1350	138	28	677	656	635	720
1350	157	28	360	339	318	318
1500	150	28	699	699	699	889
1500	169	28	381	360	360	423
1650	163	28	741	741	804	1059
1650	182	28	656	656	699	783
1800	175	28	783	826	910	1228
		35	402	402	381	445
		35	1609			
		35	550			
1800	194	28	720	741	762	953
1950	188	28	826	826	1080	1418
		35	423	423	423	487
		35	1821			
		35	593			
1950	207	28	762	826	826	1122
		35	381	381	381	445

TYPE A SHORING/TRENCH BOX - STEEL AREAS (mm ² /m)						
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)			
			H<500	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000
2100	200	28	889	889	1249	1651
		41	445	445	466	550
2100	219	28	826	826	995	1355
		35	402	402	423	487
		35	1736			
		35	593			
2250	213	28	953	953	1440	1948
		41	466	466	529	593
		41	2138			
		41	64			
2250	232	28	868	868	1164	1969
		35	423	423	487	593
		35	1990			
		35	635			
2400	225	28	1059	1016	1609	2117
		35	487	487	572	635
		35	1863			
		35	635			
2400	244	28	931	931	1355	1969
		41	445	445	529	593
		41	2011			
		41	699			
2550	238	28	1186	1101	1799	2355
		35	529	529	635	699
		35	2053			
		35	699			
2550	257	28	995	1016	1545	2117
		35	487	487	572	635
		35	1757			
		35	635			

TYPE A SHORING/TRENCH BOX - STEEL AREAS (mm ² /m)						
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)			
			H<500	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000
2700	250	28	1313	1228	1821	2355
		41	550	550	635	741
2700	269	28	1080	1080	1821	2355
		35	508	508	635	699
		35	1969			
		41	699			
		41	2350			
		41	804			
2850	267	28	1440	1376	2011	2645
		41	593	593	635	741
		41	2350			
		41	804			
2850	286	28	1228	1164	1545	2117
		35	550	550	614	699
		35	2244			
		35	741			
3000	279	28	1588	1524	2117	2712
		41	614	614	635	741
		41	2583			
		41	847			
3000	299	28	1355	1313	1736	2355
		41	593	593	635	741
		41	2265			
		41	804			

TYPE A SHORING/TRENCH BOX INSTALLATION REQUIRED FILL/COVER HEIGHT/PROOF TEST LOAD (KN/m)						
DIA. (mm)	Required Fill/Cover Height (mm)					
	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000	2000 ≤ H<3000	3000 ≤ H<4500	4500 ≤ H<7500
300	25.7	20.3	16.8	13.9	26.5	34.7
375	23.7	20.3	16.8	13.9	25.9	33.8
450	22.0	19.2	15.9	12.8	25.4	33.2
525	20.7	18.2	15.3	12.8	25.1	32.8
600	19.6	17.4	14.8	12.8	24.8	32.5
675	18.6	16.7	14.4	12.8	24.6	32.3
750	17.8	16.1	14.0	12.8	24.5	32.3
825	17.0	15.5	13.7	12.8	24.4	32.3
900	16.3	15.0	13.5	12.8	24.3	32.3
1050	15.9	14.4	13.2	12.8	24.2	32.3
1200	14.9	13.7	12.8	12.8	24.0	32.3
1350	14.8	13.1	12.8	12.8	24.0	32.3
1500	14.0	12.5	12.8	12.8	24.0	32.3
1650	14.0	12.5	12.8	12.8	24.0	32.3
1800	13.5	12.1	12.8	12.8	24.0	32.3
1950	12.9	11.7	12.8	12.8	24.0	32.3
2100	12.4	11.4	12.8	12.8	24.0	32.3
2250	11.5	11.5	12.8	12.8	24.0	32.3
2400	11.0	11.0	12.8	12.8	24.0	32.3
2550	11.0	10.4	12.8	12.8	24.0	32.3
2700	10.3	9.9	12.8	12.8	24.0	32.3
2850	9.8	9.8	12.8	12.8	24.0	32.3
3000	9.4	9.4	12.8	12.8	24.0	32.3

NOTE: THESE PROOF LOADS INCLUDE A 1.43 SAFETY FACTOR FOR FIELD CRACK CONTROL.


DESIGN TABLES AND PROOF TEST LOAD TABLE FOR CIRCULAR PIPES - TYPE A SHORING/TRENCH BOX INSTALLATION

NOTE: PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 2.

NOTES:

- 1) * INDICATES SAME STEEL AREA AS SHOWN FOR THE LESSER CONCRETE STRENGTH.
- 2) ** INDICATES A SPECIAL DESIGN IS REQUIRED. USE PAIDD SOFTWARE.
- 3) *** INDICATES THAT SHEAR CONTROL HAS BEEN REACHED. USE PAIDD FOR SPECIAL DESIGN.
- 4) ELLIPTICAL REINFORCING IS NOT ALLOWED, EXCEPT FOR QUADRANT REINFORCEMENT AND REINFORCEMENT OF ELLIPTICAL PIPE.
- 5) FOR DOUBLE CAGE RINGS OF STEEL REINFORCED PIPE, TWO AREAS ARE SHOWN. THE GREATER AREA IS FOR THE INNER CAGE STEEL AND LESSER AREA IS FOR OUTER CAGE STEEL.
- 6) FOR PIPE DIAMETERS GREATER THAN 1200 mm, USE TYPE A SHORING/TRENCH BOX DESIGN TABLES.
- 7) FOR FILL HEIGHTS GREATER THAN INDICATED, USE THE PAIDD PROGRAM.
- 8) H = DESIGN FILL HEIGHT, mm.
- 9) SUBSTITUTION OF PIPES UNDER FILLS OF 1000 mm OR LESS IS PERMITTED ONLY WITH DESIGNER APPROVAL.
- 10) USE PAIDD SOFTWARE ONLY FOR PIPE DESIGNS NOT PROVIDED BY BD-636M.
- 11) STEEL AREAS SPECIFIED IN THE FILL HEIGHT / STEEL AREA TABLES ARE TO BE ACHIEVED USING ONE LAYER OF REINFORCEMENT FOR EACH CAGE. TWO LAYERS MAY BE SUBSTITUTED FOR ONE LAYER PROVIDED THE SUM OF THE STEEL AREAS OF THE TWO LAYERS IS EQUAL TO THE AREA OF STEEL FOR THE SINGLE LAYER CAGE. WHEN SUBSTITUTING, SPACING OF REINFORCEMENT IS TO REMAIN THE SAME. DESIGNING FOR TWO LAYERS OF REINFORCEMENT AND PROVIDING ONE LAYER OF REINFORCEMENT OF EQUIVALENT AREA IS NOT PERMITTED.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

LEGEND
 = FOR INFORMATION ONLY. PROOF LOAD TEST MUST BE PERFORMED TO THE MAXIMUM PROOF TEST LOAD FOR THE RANGE OF ITEM NUMBER.

COMMONWEALTH OF PENNSYLVANIA
 DEPARTMENT OF TRANSPORTATION
 BUREAU OF DESIGN
 STANDARD REINFORCED CONCRETE PIPES
 DESIGN TABLES

DESIGN TABLES AND PROOF TEST LOAD TABLE FOR CIRCULAR PIPES - TYPE B SHORING/TRENCH BOX INSTALLATION

TYPE B SHORING/TRENCH BOX - STEEL AREAS (mm ² /m)						
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)			
			H<500	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000
300	50	28				169
300	69	28				148
375	57	28				169
375	75	28				148
450	63	28				233
450	82	28				191
525	69	28				275
525	88	28				233
600	75	28				339
600	94	28				275
675	82	28				402
675	100	28				339
750	88	28	614	466	360	318
750	107	28	529	381	318	275
825	94	28	699	529	423	360
825	113	28	593	445	360	318

TYPE B SHORING/TRENCH BOX - STEEL AREAS (mm ² /m)						
DIA. (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)			
			H<500	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000
900	100	28	741	572	445	423
900	119	28	614	508	402	360
900	100	28	572	445	360	318
		35	318	148	169	148
900	119	28	466	360	296	275
		35	254	191	148	148
1050	113	28	593	508	466	699
		35	318	275	233	212
1050	132	28	487	445	381	402
		35	254	212	191	169
		35	169	212	191	233
1200	113	28	614	593	529	550
		35	339	296	275	254
1200	132	28	508	508	466	466
		35	275	254	254	212

TYPE B SHORING/TRENCH BOX INSTALLATION REQUIRED FILL/COVER HEIGHT/PROOF TEST LOAD (KN/m)						
DIA. (mm)	Required Fill/Cover Height (mm)					
	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000	2000 ≤ H<3000	3000 ≤ H<4500	4500 ≤ H<7500
300	24.4	20.3	16.8	13.9	25.2	33.0
375	22.5	19.2	15.9	12.8	24.6	32.1
450	20.9	18.2	15.3	12.8	24.1	31.6
525	19.7	17.3	14.5	12.8	23.8	31.2
600	18.6	16.5	14.1	12.8	23.6	30.9
675	17.7	15.9	13.7	12.8	23.4	30.6
750	16.9	15.3	13.3	12.8	23.3	30.5
825	16.2	14.7	13.0	12.8	23.1	30.3
900	15.5	14.1	12.8	12.8	23.0	30.2
1050	15.2	13.7	12.8	12.8	22.9	30.1
1200	14.2	13.0	12.8	12.8	22.9	30.1

NOTE: THESE PROOF LOADS INCLUDE A 1.43 SAFETY FACTOR FOR FIELD CRACK CONTROL.

TYPE A STANDARD INSTALLATION HORIZONTAL ELLIPTICAL PIPE H<500				
EQUIV. ROUND (mm)	RISE/ SPAN (mm)	WALL THICK. (mm)	f' c (MPa)	Steel Area (mm ² /m)
450	365/575	69	28	**
			35	423
600	490/770	82	28	**
675	550/865	88	28	**
			35	**
			41	**
750	610/960	94	28	466
				466
825	670/1055	94	28	529
				529
900	730/1150	113	28	444
				444
1050	855/1345	125	28	487
				487
1200	975/1535	138	28	508
				508
1350	1095/1730	150	28	550
				550
1500	1220/1920	163	28	593
				593
1650	1340/2110	175	28	635
				635
1800	1465/2305	188	28	699
				699
1950	1585/2495	200	28	762
				762
2100	1705/2690	213	28	831
				831
2250	1830/2880	225	28	1058
				1058
2400	1950/3070	238	28	1270
				1270
2550	2075/3265	244	28	1502
				1502
2700	2195/3455	250	28	1820
				1820
2850	2315/3648	267	28	2010
				2010
3000	2440/3840	279	28	2286
				2286

TYPE B STANDARD INSTALLATION HORIZONTAL ELLIPTICAL PIPE H<500				
EQUIV. ROUND (mm)	RISE/ SPAN (mm)	WALL THICK. (mm)	f' c (MPa)	Steel Area (mm ² /m)
450	365/575	69	28	423
600	490/770	82	28	**
			35	**
			41	613
675	550/865	88	28	**
			35	**
			41	**
750	610/960	94	28	445
				445
825	670/1055	94	28	487
				487
900	730/1150	113	28	423
				423
1050	855/1345	125	28	466
				466
1200	975/1535	138	28	486
				486
1350	1095/1730	150	28	529
				529
1500	1220/1920	163	28	572
				572
1650	1340/2110	175	28	614
				614
1800	1465/2305	188	28	677
				677
1950	1585/2495	200	28	720
				720
2100	1705/2690	213	28	889
				889
2250	1830/2880	225	28	995
				995
2400	1950/3070	238	28	1185
				1185
2550	2075/3265	244	28	1502
				1502
2700	2195/3455	250	28	1736
				1736
2850	2315/3648	267	28	1905
				1905
3000	2440/3840	279	28	2159
				2159

NOTES:

- 1) * INDICATES SAME STEEL AREA AS SHOWN FOR THE LESSER CONCRETE STRENGTH.
- 2) ** INDICATES A SPECIAL DESIGN IS REQUIRED. USE PAIDD SOFTWARE.
- 3) ELLIPTICAL REINFORCING IS NOT ALLOWED, EXCEPT FOR QUADRANT REINFORCEMENT AND REINFORCEMENT OF ELLIPTICAL PIPE.
- 4) FOR DOUBLE CIRCULAR STEEL REINFORCED PIPE, TWO AREAS ARE SHOWN. THE GREATER AREA IS FOR THE INNER CAGE STEEL AND LESSER AREA IS FOR OUTER CAGE STEEL.
- 5) *** INDICATES A SHEAR CONTROL HAS BEEN REACHED. USE PAIDD SOFTWARE FOR SPECIAL DESIGN.
- 6) H = DESIGN FILL HEIGHT, mm.
- 7) SUBSTITUTION OF PIPES UNDER FILLS OF 1000 mm OR LESS IS PERMITTED ONLY WITH DESIGNER APPROVAL.
- 8) FOR DESIGN OF A TYPE A STANDARD ELLIPTICAL PIPE FOLLOW THESE STEPS:
 - (a) SELECT THE LARGER DIMENSION OF SPAN OR RISE FROM ELLIPTICAL PIPE SIZES SHOWN IN THE TYPE A SHORING/TRENCH BOX TABLE FOR ELLIPTICAL PIPES. I.E. RISE DIMENSION FOR VERTICAL ELLIPTICAL SPAN DIMENSION FOR HORIZONTAL ELLIPTICAL
 - (b) GO TO TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPES.
 - (c) USE THE RISE DIMENSION FOR VERTICAL ELLIPTICAL DESIGNS OR THE SPAN DIMENSION FOR THE HORIZONTAL ELLIPTICAL DESIGNS AS THE DIAMETER IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPE. [IF THE SELECTED DIAMETER IS NOT AVAILABLE IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPE, USE THE NEXT LARGER AVAILABLE DIAMETER IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPE TO DETERMINE THE STEEL AREA.]
 - (d) FOR THE SELECTED DIAMETER, WALL THICKNESS, DESIGN FILL HEIGHT AND CONCRETE STRENGTH, DETERMINE THE AREA OF STEEL REQUIRED FOR THE INNER CAGE OF THE PIPE IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPES. USE THIS AREA FOR EACH, INNER AND OUTER, CAGE FOR THE ELLIPTICAL PIPE DESIGN.
- 9) USE PAIDD SOFTWARE ONLY FOR PIPE DESIGNS NOT PROVIDED BY BD-636M.
- 10) STEEL AREAS SPECIFIED IN THE FILL HEIGHT / STEEL AREA TABLES ARE TO BE ACHIEVED USING ONE LAYER OF REINFORCEMENT FOR EACH CAGE. TWO LAYERS MAY BE SUBSTITUTED FOR ONE LAYER PROVIDED THE SUM OF THE STEEL AREAS OF THE 2 LAYERS IS EQUAL TO THE AREA OF STEEL FOR THE SINGLE LAYER CAGE. WHEN SUBSTITUTING, SPACING OF REINFORCEMENT IS TO REMAIN THE SAME. DESIGNING FOR 2 LAYERS OF REINFORCEMENT AND PROVIDING ONE LAYER OF REINFORCEMENT OF EQUIVALENT AREA IS NOT PERMITTED.

DESIGN TABLES FOR HORIZONTAL ELLIPTICAL PIPE-STANDARD INSTALLATION- TYPE A / TYPE B

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF DESIGN

STANDARD
REINFORCED CONCRETE PIPES
ELLIPTICAL PIPE DESIGN TABLES

RECOMMENDED 6-9-10 <i>Thos P. Moore</i> CHIEF BRIDGE ENGINEER	RECOMMENDED 6-9-10 <i>Bruce S. Johnson</i> DIRECTOR, BUREAU OF DESIGN	SHEET 8 OF 18 BD-636M
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TYPE A SH/T BOX VERTICAL ELLIPTICAL PIPE - STEEL AREAS (mm ² /m)											
EQUIV. ROUND (mm)	RISE/SPAN (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)							
				H=500	500 ≤ H < 600	600 ≤ H < 1000	1000 ≤ H < 2000	2000 ≤ H < 3000	4500	6000	7500
900	1150/730	113	28	**	487	402	296	254	318	402	487
				**	254	212	148	148	148	169	191
1050	1345/855	125	28	**	593	487	360	318	381	487	593
				**	296	254	191	169	148	191	254
1200	1535/975	138	28	**	423	381	318	318	423	529	656
				**	212	191	169	169	233	275	
1350	1730/1095	150	28	**	445	402	381	381	487	614	**
				**	233	212	191	191	212	254	**
			35	**	*	*	*	*	*	*	635
				**	*	*	*	*	*	*	275
1500	1920/1220	163	28	**	466	466	423	445	572	699	**
				**	233	233	212	233	233	296	**
			35	**	*	*	*	*	*	*	720
				**	*	*	*	*	*	*	318
1650	2110/1340	175	28	**	508	487	466	487	656	804	**
				**	254	254	233	254	275	339	**
			35	**	*	*	*	*	*	*	826
				**	*	*	*	*	*	*	360
1800	2305/1465	188	28	**	529	529	529	550	720	**	**
				**	275	275	275	275	318	**	**
			35	**	*	*	*	*	*	783	931
				**	*	*	*	*	*	339	402
1950	2495/1585	200	28	**	550	550	571	614	804	**	**
				**	275	275	296	318	339	**	**
			35	**	*	*	*	*	*	868	1016
				**	*	*	*	*	*	381	445
2100	2690/1705	213	28	**	593	593	614	699	889	**	**
				**	296	296	318	360	381	**	**
			35	**	*	*	*	*	*	953	**
				**	*	*	*	*	*	423	**
			41	**	*	*	*	*	*	1122	**
				**	*	*	*	*	*	487	**
2250	2880/1830	225	28	**	614	614	635	741	953	**	**
				**	318	318	318	381	402	**	**
			35	**	*	*	*	*	*	1016	**
				**	*	*	*	*	*	445	**
			41	**	*	*	*	*	*	1186	**
				**	*	*	*	*	*	508	**
2400	3070/1950	238	28	**	656	656	699	804	1037	**	**
				**	339	339	360	402	445	**	**
			35	**	*	*	*	*	*	1101	**
				**	*	*	*	*	*	487	**
			41	**	*	*	*	*	*	1291	**
				**	*	*	*	*	*	550	**
2550	3265/2075	244	28	**	720	720	783	910	**	**	**
				**	360	360	402	466	**	**	**
			35	**	*	*	*	*	1016	1228	**
				**	*	*	*	*	445	529	**
			41	**	*	*	*	*	*	1545	**
				**	*	*	*	*	*	635	**
2700	3455/2195	250	28	**	762	762	868	1037	**	**	**
				**	381	381	445	529	**	**	**
			35	**	*	*	*	*	1122	1461	**
				**	*	*	*	*	508	593	**
			41	**	*	*	*	*	*	1821	**
				**	*	*	*	*	*	699	**
2850	3648/2315	267	28	**	826	826	931	1164	**	**	**
				**	423	423	466	593	**	**	**
			35	**	*	*	*	*	1207	**	**
				**	*	*	*	*	529	**	**
			41	**	*	*	*	*	*	1461	**
				**	*	*	*	*	*	635	**
3000	3840/2440	279	28	**	868	868	1016	1397	**	**	**
				**	445	445	508	699	**	**	**
			35	**	*	*	*	*	1291	**	**
				**	*	*	*	*	572	**	**
			41	**	*	*	*	*	*	1609	**
				**	*	*	*	*	*	677	**

PROOF TEST LOAD TABLE FOR VERTICAL ELLIPTICAL PIPE TYPE A SHORING TRENCH - BOX INSTALLATION (kN/m)										
EQUIV. ROUND (mm)	RISE/SPAN (mm)	500 ≤ H < 600	600 ≤ H < 1000	1000 ≤ H < 2000	2000 ≤ H < 3000	3000 ≤ H < 4500	4500 ≤ H < 6000	6000 ≤ H < 7500	PROOF TEST	
									LOAD TABLE FOR VERTICAL ELLIPTICAL PIPE	TYPE A SHORING TRENCH - BOX INSTALLATION (kN/m)
900	1150/730	14.7	13.9	13.5	17.2	24.5	32.1	39.8		
1050	1345/855	13.6	13.0	13.3	17.1	24.3	31.8	39.5		
1200	1535/975	13.4	12.6	16.2	21.4	30.8	40.5	50.4		
1350	1730/1095	12.6	12.0	16.1	21.2	30.6	40.3	50.2		
1500	1920/1220	11.9	11.5	15.9	21.1	30.5	40.2	49.9		
1650	2110/1340	11.9	11.1	15.8	21.0	30.4	40.0	49.8		
1800	2305/1465	11.3	10.7	15.7	20.9	30.3	39.9	49.6		
1950	2495/1585	11.4	10.7	15.6	20.8	30.2	39.8	49.5		
2100	2690/1705	10.9	10.4	15.5	20.8	30.1	39.7	49.4		
2250	2880/1830	10.6	10.1	15.4	20.7	30.1	39.7	49.3		
2400	3070/1950	10.2	9.9	15.4	20.6	30.0	39.6	49.3		
2550	3265/2075	9.9	9.6	15.3	20.6	30.0	39.6	49.2		
2700	3455/2195	9.7	9.7	15.2	20.5	29.9	39.5	49.1		
2850	3648/2315	9.5	9.5	15.2	20.5	29.9	39.5	49.1		
3000	3840/2440	9.1	9.1	15.1	20.5	29.8	39.4	49.0		

NOTE:

PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 3.

TYPE A SH/T BOX HORIZONTAL ELLIPTICAL PIPE - STEEL AREAS (mm ² /m)										
EQUIV. ROUND (mm)	RISE/SPAN (mm)	WALL THICK. (mm)	f'c (MPa)	Required Fill/Cover Height (mm)						
				H=500	500 ≤ H < 600	600 ≤ H < 1000	1000 ≤ H < 2000	2000 ≤ H < 3000	4500	6000
450	365/575	69	28	**	529	402	296	275		
600	490/770	82	28	**	783	572	423	381		
675	550/865	88	28	**	826	699	529	466		
750	610/960	94	28	**	826	614	508	593		
				**	826	614	508	593		
825	670/1055	94	28	**	1016	741	614	847		
				**	1016	741	614	847		
900	730/1150	113	28	**	699	677	572	677		
				**	699	677	572	677		
1050	855/1345	125	28	**	741	741	699	953		
				**	741	741	699	953		
1200	975/1535	138	28	**	783	826	889	1186		
				**	78	826	889	1186		
1350	1095/1730	150	28	**	910	953	1143	1503		
				**	910	953	1143	1503		
1500	1220/1920	163	28	**	1059	1143	1397	**		
				**	1059	1143	1397	**		
			35	**	*	*	*	1715		
				**	*	*	*	1715		
1650	1340/2110	175	28	**	1207	1270	1630	**		
				**	1207	1270	1630	**		
			35	**	*	*	*	1990		
				**	*	*	*	1990		
1800	1465/2305	188	28	**	1397	1482	1948	**		
				**	1397	1482	1948	**		
			41	**	*	*	*	2181		
				**	*	*	*	2181		
1950	1585/2495	200	28	**	1545	1651	**	**		
				**	1545	1651	**	**		
			35	**	*	*	*	2075	**	**
				**	*	*	*	2075	**	**
			41	**	*	*	*	2456	**	**
				**	*	*	*	2456	**	**
2100	1705/2690	213	28	**	1778	1884	**	**		
				**	1778	1884	**	**		
			41	**	*	*	*	2265	**	**
				**	*	*	*	2265	**	**
2250	1830/2880	225	28	**	1948	2096	**	**		
				**	1948	2096	**	**		
2400	1950/3070	238	28	**	2244	**	**	**		
				**	2244	**	**	**		
			35	**	*	*	*	2202	**	**
				**	*	*	*	2202	**	**
			48	**	*	*	*	2773	**	**
				**	*	*	*	2773	**	**
2550	2075/3265	244	35	**	2392	2562	**	**		
				**	2392	2562	**	**		
			41	**	*	*	*	3218	**	**
				**	*	*	*	3218	**	**
2700	2195/3455	250	35	**	2794	**	**	**		
				**	2794	**	**	**		
			41	**	*	*	*	2816	**	**
				**	*	*	*	2816	**	**
2850	2315/3648	267	35	**	3027	**	**	**		
				**	3027	**	**	**		
			41	**	*	*	*	3048	**	**
				**	*	*	*	3048	**	**
3000	2440/3840	279	28	**	**	**	**	**		
				**	**	**	**	**		

PROOF TEST LOAD TABLE FOR HORIZONTAL ELLIPTICAL PIPE TYPE A SHORING TRENCH - BOX INSTALLATION (kN/m)										
EQUIV. ROUND (mm)	RISE/SPAN (mm)	500 ≤ H < 600	600 ≤ H < 1000	1000 ≤ H < 2000	2000 ≤ H < 3000	3000 ≤ H < 4500	4500 ≤ H < 6000	6000 ≤ H < 7500	PROOF TEST	
									LOAD TABLE FOR HORIZONTAL ELLIPTICAL PIPE	TYPE A SHORING TRENCH - BOX INSTALLATION (kN/m)
450	365/575	23.3	19.9	16.1	17.8	25.0	32.6	40.4		
600	490/770	21.1	18.4	15.3	17.4	24.5	32.1	39.8		
675	550/865	20.1	17.7	14.9	17.3	24.4	31.9	39.5		
750	610/960	20.3	17.3	16.8	21.6	30.9	40.6	50.4		

TYPE B SH/T BOX VERTICAL ELLIPTICAL PIPE - STEEL AREAS (mm ² /m)											
EQUIV. ROUND (mm)	RISE/SPAN (mm)	WALL THICK. (mm)	f' c (MPa)	Required Fill/Cover Height (mm)							
				H=500	500 ≤ H<1000	1000 ≤ H<2000	2000 ≤ H<3000	4500	6000	7500	
900	1150/730	113	28	**	466	381	275	233	339	423	529
				**	275	233	169	148	-	-	-
1050	1345/855	125	28	**	572	466	339	296	423	529	677
				**	339	275	212	148	-	-	-
1200	1535/975	138	28	**	402	360	296	296	423	550	826
				**	212	191	148	148	212	275	423
1350	1730/1095	150	28	**	423	423	360	360	487	635	1101
				**	212	212	169	148	254	318	550
1500	1920/1220	163	28	**	445	445	402	402	572	804	1418
				**	233	212	191	169	296	339	720
1650	2110/1340	175	28	**	466	466	445	466	635	1037	**
				**	233	233	212	212	318	529	**
				35	**	*	*	*	*	*	1291
				**	*	*	*	*	*	*	656
1800	2305/1465	188	28	**	487	487	487	529	720	1291	**
				**	254	233	233	233	360	677	**
				41	**	*	*	*	*	*	1567
				**	*	*	*	*	*	*	783
1950	2495/1585	200	28	**	529	529	550	593	847	1588	**
				**	254	254	254	254	423	804	**
				41	**	*	*	*	*	*	1503
				**	*	*	*	*	*	*	762
2100	2690/1705	213	28	**	550	550	572	656	974	**	**
				**	275	275	275	296	487	**	**
				35	**	*	*	*	*	*	1334
				**	*	*	*	*	*	*	677
				41	**	*	*	*	*	*	1715
				**	*	*	*	*	*	*	889
2250	2880/1830	225	28	**	572	572	614	699	1080	**	**
				**	275	275	275	318	550	**	**
				35	**	*	*	*	*	*	1503
				**	*	*	*	*	*	*	762
2400	3070/1950	238	28	**	614	614	656	762	1313	**	**
				**	296	296	296	339	656	**	**
				35	**	*	*	*	*	*	1757
				**	*	*	*	*	*	*	889
2550	3265/2075	244	28	**	656	677	741	847	1672	**	**
				**	318	318	318	381	847	**	**
				41	**	*	*	*	*	*	1757
				**	*	*	*	*	*	*	889
2700	3455/2195	250	28	**	720	720	804	974	**	**	**
				**	339	339	360	423	**	**	**
				35	**	*	*	*	*	*	1524
				**	*	*	*	*	*	*	762
2850	3648/2315	267	28	**	762	762	889	1101	**	**	**
				**	360	360	402	466	**	**	**
				35	**	*	*	*	*	*	1694
				**	*	*	*	*	*	*	847
3000	3840/2440	279	28	**	804	826	953	1228	**	**	**
				**	381	381	423	487	**	**	**
				35	**	*	*	*	*	*	1905
				**	*	*	*	*	*	*	953

PROOF TEST LOAD TABLE FOR VERTICAL ELLIPTICAL PIPE TYPE B SHORING TRENCH - BOX INSTALLATION (kn/m)										
EQUIV. ROUND (mm)	RISE/SPAN (mm)	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000	2000 ≤ H<3000	3000 ≤ H<4500	4500 ≤ H<6000	6000 ≤ H<7500	Required Fill/Cover Height (mm)	
									4500	6000
900	1150/730	14.0	13.2	12.8	16.4	23.3	30.5	37.8	45.0	52.5
1050	1345/855	12.9	12.3	12.6	16.2	23.1	30.2	37.5	44.5	52.0
1200	1535/975	12.8	12.0	15.4	20.3	29.3	38.5	47.9	55.0	62.5
1350	1730/1095	12.0	11.4	15.3	20.2	29.1	38.3	47.6	54.5	62.0
1500	1920/1220	11.3	8.0	15.1	20.0	29.0	38.1	47.5	54.0	61.5
1650	2110/1340	11.3	10.5	15.0	19.9	28.8	38.0	47.3	53.5	61.0
1800	2305/1465	10.7	10.1	14.9	19.9	28.8	37.9	47.2	53.0	60.5
1950	2495/1585	10.8	10.1	14.8	19.8	28.7	37.8	47.0	52.5	60.0
2100	2690/1705	10.4	9.8	14.7	19.7	28.6	37.7	46.9	52.0	59.5
2250	2880/1830	10.1	9.6	14.7	19.7	28.6	37.7	46.9	51.5	59.0
2400	3070/1950	9.7	9.4	14.6	19.6	28.5	37.6	46.8	51.0	58.5
2550	3265/2075	9.4	9.2	14.5	19.6	28.5	37.6	46.7	50.5	58.0
2700	3455/2195	9.2	9.2	14.5	19.5	28.4	37.5	46.7	50.0	57.5
2850	3648/2315	9.0	9.0	14.4	19.5	28.4	37.5	46.6	49.5	57.0
3000	3840/2440	8.7	8.7	14.4	19.4	28.3	37.4	46.6	49.0	56.5

NOTE:

PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 3.

TYPE B SH/T BOX HORIZONTAL ELLIPTICAL PIPE - STEEL AREAS (mm ² /m)											
EQUIV. ROUND (mm)	RISE/SPAN (mm)	WALL THICK. (mm)	f' c (MPa)	Required Fill/Cover Height (mm)							
				H=500	500 ≤ H<1000	1000 ≤ H<2000	2000 ≤ H<3000	4500	6000	7500	
450	365/575	69	28	**	466	381	275	254	-	-	-
600	490/770	82	28	**	677	529	402	360	-	-	-
675	550/865	88	28	**	804	656	487	445	-	-	-
750	610/960	94	28	**	720	572	466	550	-	-	-
				**	720	572	466	550	-	-	-
825	670/1055	94	28	**	783	699	572	804	-	-	-
				**	783	699	572	804	-	-	-
900	730/1150	113	28	**	635	635	529	635	-	-	-
				**	635	635	529	635	-	-	-
1050	855/1345	125	28	**	699	699	677	910	-	-	-
				**	699	699	677	910	-	-	-
1200	975/1535	138	28	**	783	783	847	1122	-	-	-
				**	783	783	847	1122	-	-	-
1350	1095/1730	150	28	**	910	910	1080	1418	-	-	-
				**	910	910	1080	1418	-	-	-
1500	1220/1920	163	28	**	1080	1080	1334	1736	-	-	-
				**	1080	1080	1334	1736	-	-	-
1650	1340/2110	175	28	**	1207	1207	1545	1884	-	-	-
				**	1207	1207	1545	1884	-	-	-
1800	1465/2305	188	28	**	1418	1418	1842	2181	-	-	-
				**	1418	1418	1842	2181	-	-	-
1950	1585/2495	200	28	**	1567	1567	**	**	-	-	-
				**	1567	1567	**	**	-	-	-
				35	**	*	*	*	*	*	1969
				**	*	*	*	*	*	*	1969
				41	**	*	*	*	*	*	2329
				**	*	*	*	*	*	*	2329
2100	1705/2690	213	28	**	1799	1799	**	**	-	-	-
				**	1799	1799	**	**	-	-	-
				35	**	*	*	*	*	*	2286
				**	*	*	*	*	*	*	2286
2250	1830/2880	225	28	**	1990	1990	**	**	-	-	-
				**	1990	1990	**	**	-	-	-
				41	**	*	*	*	*	*	2413
				**	*	*	*	*	*	*	2413
2400	1950/3070	238	28	**	2244	2244	**	**	-	-	-
				**	2244	2244	**	**	-	-	-
				41	**	*	*	*	*	*	2752
				**	*	*	*	*	*	*	2752
2550	2075/3265	244	35	**	2413	2413	**	**	-	-	-
				**	2413	2413	**	**	-	-	-
2700	2195/3455	250	35	**	2816	2816	**	**	-	-	-
				**	2816	2816	**	**	-	-	-
2850	2315/3648	267	35	**	3048	3048	**	**	-	-	-
				**	3048	3048	**	**	-	-	-
3000	2440/3840	279	28	**	**	**	**	**	-	-	-
				**	**	**	**	**	-	-	-

PROOF TEST LOAD TABLE FOR HORIZONTAL ELLIPTICAL PIPE TYPE B SHORING TRENCH - BOX INSTALLATION (kn/m)										
EQUIV. ROUND (mm)	RISE/SPAN (mm)	500 ≤ H<600	600 ≤ H<1000	1000 ≤ H<2000	2000 ≤ H<3000	3000 ≤ H<4500	4500 ≤ H<6000	6000 ≤ H<7500	Required Fill/Cover Height (mm)	
									4500	6000
450	365/575	22.1	18.9	15.3	16.9	23.7	31.0	38.4	45.0	52.5
600	490/770	20.1	17.5	14.5	16.6	23.3	30.5	37.8	45.0	52.5
675	550/865	19.1	16.8	14.1	16.4	23.2	30.3	37.5	44.5	52.0
750	610/960	19.3	16.4	15.9	20.6	29.4	38.6	47.9	55.0	62.5
825	670/1055	18.5	15.9	15.8	20.5	29.2	38.4	47.7	54.5	62.0
900	730/1150	17.9	15.5	15.8	20.4	29.2	38.3	47.6	54.0	61.5
1050	855/1345	17.6	14.7	15.6	20.2	29.1	38.1	47.3	53.5	61.0
1200	975/1535	16.6	14.0	15.5	20.1	28.9	37.9	47.1	53.0	60.5
1350	1095/1730	16.6	14.0	15.4	20.0	28.7	37.8	47.0	52.5	60.0
1500	1220/1920	15.7	13.4	15.3	20.0	28.7	37.7	46.9	52.0	59.5
1650	1340/2110	15.0	13.0	15.2	19.9	28.6	37.6	46.8	51.5	59.0
1800	1465/2305	13.4	13.0	15.1	19.8	28.5	37.5	46.7	51.0	58.5
1950	1585/2495	13.9	12.2	15.0	19.8	28.5	37.5	46.6	50.5	58.0
2100	1705/2690	12.6	11.3	15.0	19.7	28.4	37.4	46.6	50.0	57.5
2250	1830/2880	11.7	11.1	14.9	19.7	28.4	37.4	46.5	49.5	57.0
2400	1950/3070	10.8	10.4	14.8	19.6	28.3	37.3			

TABLE A

DESIGN DATA				
ITEMS	STANDARD INSTALLATION		TRENCH BOX/SHORING INSTALLATION	
	TYPE A	TYPE B	TYPE A	TYPE B
INSTALLATION TYPE	PAIDD	PAIDD	PAIDD	PAIDD
HAUNCH COMPACTION	95% MIN.	95% MIN.	60% MIN.	60% MIN.
SOIL WEIGHT	140 lbs./ft. ³	140 lbs./ft. ³	140 lbs./ft. ³	140 lbs./ft. ³
LIVE LOAD	HS 25	HS 25	HS 25	HS 25
f _y	65,000 psi	65,000 psi	65,000 psi	65,000 psi
f'c	MIN. 4,000 psi	MIN. 4,000 psi	MIN. 4,000 psi	MIN. 4,000 psi
CONCRETE COVER	1" OVER STEEL	1" OVER STEEL	1" OVER STEEL	1" OVER STEEL
LOAD FACTORS ¹	TYPE A	TYPE B	TYPE A	TYPE B
DEAD LOAD & EARTH LOAD FACTOR (SHEAR & MOMENT)	1.30	1.30	1.30	1.30
DEAD LOAD FACTOR (THRUST) ²				
REINFORCEMENT DESIGN	1.00	1.00	1.00	1.00
CONCRETE COMPRESSION	1.30	1.30	1.30	1.30
LIVE LOAD FACTOR (SHEAR & MOMENT)	2.17	2.17	2.17	2.17
LIVE LOAD FACTOR (THRUST)	1.00	1.00	1.00	1.00
INTERNAL PRESSURE LOAD FACTORS (THRUST)	1.50	1.50	1.50	1.50
IMPACT (TO MAX. 8' HEIGHT)	40 [1.0-0.125H] ≥ 10%	40 [1.0-0.125H] ≥ 10%	40 [1.0-0.125H] ≥ 10%	40 [1.0-0.125H] ≥ 10%
STRENGTH REDUCTION (Φ FACTORS) ³	TYPE A	TYPE B	TYPE A	TYPE B
FLEXURE	0.90	0.95	0.90	0.95
RADIAL TENSION	0.85	0.90	0.85	0.90
DIAGONAL TENSION	0.85	0.90	0.85	0.90
CRACK CONTROL FACTOR	0.7	0.7	0.7	0.7
ORIENTATION ANGLE	±10°	±10°	±10°	±10°
MATERIAL & PROCESS FACTORS ⁴	TYPE A	TYPE B	TYPE A	TYPE B
RADIAL TENSION	1.0	1.0	1.0	1.0
DIAGONAL TENSION	1.0	1.0	1.0	1.0
EMBANKMENT ARCHING FACTORS ⁵				
VAF (VERTICAL)	1.35	1.35	SEE TABLE 'C'	SEE TABLE 'C'
HAF (HORIZONTAL)	0.45	0.45		

TABLE B

ARCHING COEFFICIENTS															
INSTALLATION TYPE	VAF	HAF	A1	A2	A3	A4	A5	A6	a	b	c	e	f	u	v
EMBANKMENT	1.35	0.45	0.62	0.73	1.35	0.19	0.08	0.18	1.40	0.40	0.18	0.08	0.05	0.80	0.80
TRENCH BOX OR SHORING	*	*	1.45	0.00	1.45	0.00	0.11	0.19	1.45	0.30	0.25	0.00	--	0.90	--

* SEE TABLE 'C'

TABLE C

FACTORS FOR TRENCH BOX OR SHORING INSTALLATION*				
REQUIRED FILL HEIGHT FT.	12" THROUGH 36" DIAMETER		42" THROUGH 120" DIAMETER	
	VAF	HAF	VAF	HAF
1.5	1.20	0.29	1.20	0.29
2.0	1.15	0.29	1.20	0.29
3.0	1.00	0.25	1.20	0.25
7.0	0.70	0.18	0.90	0.18
10.0	0.70	0.16	0.90	0.16
15- 25	0.70	0.12	0.80	0.12

* BEDDING FACTOR USED TO DETERMINE PROOF TEST LOAD 1.60 FOR EARTH LOADS. LIVE LOAD BEDDING FACTOR AS PER ACPA "DESIGN DATA 40" DECEMBER, 1992.

TABLE D

FACTORS FOR TRENCH BOX OR SHORING INSTALLATION FOR ELLIPTICAL PIPE										
REQUIRED FILL HEIGHT FT.	EQUIVALENT ROUND		HORIZONTAL ELLIPTICAL				VERTICAL ELLIPTICAL			
	VAF	HAF	VAF		HAF		VAF		HAF	
			12" to 36"	42" to 120"	12" to 36"	42" to 120"	12" to 36"	42" to 120"		
1.5	1.20	0.29	1.20	1.20	0.18	0.18	1.20	1.20	0.46	0.46
2.0	1.10	0.22	1.15	1.20	0.18	0.18	1.15	1.20	0.46	0.46
3.0	1.10	0.22	1.00	1.20	0.16	0.16	1.00	1.20	0.40	0.40
7.0	0.90	0.16	0.70	0.90	0.10	0.10	0.70	0.90	0.29	0.29
10.0	0.80	0.12	0.70	0.90	0.10	0.10	0.70	0.90	0.25	0.25
15- 25			0.70	0.90	0.08	0.08	0.70	0.90	0.19	0.19

GENERAL NOTE:

FOR SHEETS 11 THROUGH 18, ALL DIMENSIONS ARE IN U.S. CUSTOMARY UNITS (FEET AND INCHES) UNLESS OTHERWISE NOTED. FOR METRIC UNIT DETAILS, SEE SHEETS 1 THROUGH 9.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
BUREAU OF DESIGN

STANDARD
REINFORCED CONCRETE PIPES
DESIGN CRITERIA


RECOMMENDED 6-9-10 <i>Thad Moring</i> CHIEF BRIDGE ENGINEER	RECOMMENDED 6-9-10 <i>Brad Thomas</i> DIRECTOR, BUREAU OF DESIGN	SHEET 11 OF 18 BD-636M
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TYPE B STANDARD INSTALLATION - STEEL AREAS (in. ² /ft.)																						
Dia.	Wall Thick.	f'c (psi)	Required Fill/Cover Height (mm)																			
			H < 1.5'	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'	15'	20'	25'	30'	40'	50'	H > 50'								
12"	2"	4000	0.09	*	*	*	0.08	*	*	*	*	*	*	0.12	**	**						
		5000	*	*	*	*	*	*	*	*	*	*	*	*	0.16	**						
12"	2 1/4"	4000	0.08	*	*	*	0.08	*	*	*	*	*	*	0.08	*	**						
15"	2 1/4"	4000	0.11	*	*	*	0.08	*	*	*	*	*	*	0.09	0.11	0.19	**					
		6000	*	*	*	*	*	*	*	*	*	*	*	*	*	0.19	**					
15"	3"	4000	0.08	*	*	*	0.07	*	*	*	*	*	*	0.07	0.09	0.12	0.16	**				
18"	2 1/2"	4000	0.13	*	*	*	0.08	*	*	*	*	*	*	0.10	0.12	0.15	**	**				
		5000	*	*	*	*	*	*	*	*	*	*	*	*	*	0.21	**	**				
18"	3 1/4"	4000	0.12	*	*	*	0.07	*	*	*	*	*	*	0.08	0.10	0.11	0.16	**	**			
21"	2 3/4"	4000	0.17	0.11	*	0.07	*	*	*	0.09	0.12	0.16	0.19	**	**	**	**	**				
21"	3 1/2"	4000	0.16	0.07	*	0.07	*	*	*	0.08	0.10	0.12	0.15	0.23	**	**	**	**				
24"	3"	4000	0.22	0.14	*	0.10	*	*	*	0.11	0.15	0.19	0.24	**	**	**	**	**				
24"	3 3/4"	4000	0.22	0.12	*	0.08	*	*	*	0.09	0.12	0.15	0.18	0.30	**	**	**	**				
27"	3 1/4"	4000	**	0.16	0.11	0.10	0.10	0.10	0.13	0.18	0.22	0.30	**	**	**	**	**	**				
		5000	0.26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**	**		
27"	4"	4000	**	0.14	0.10	0.08	0.08	0.11	0.14	0.18	0.22	**	**	**	**	**	**	**	**			
		5000	0.25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**	**	
30"	3 1/2"	4000	**	0.18	0.13	0.13	0.16	0.21	0.26	**	**	**	**	**	**	**	**	**	**	**		
		5000	**	*	*	*	*	*	*	*	*	0.31	**	**	**	**	**	**	**	**	**	
		6000	0.29	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**	
30"	4 1/4"	4000	**	0.16	0.12	0.12	0.13	0.17	0.21	0.25	**	**	**	**	**	**	**	**	**	**	**	
		6000	0.27	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**
33"	3 3/4"	4000	**	0.21	0.16	0.16	0.18	0.24	0.31	**	**	**	**	**	**	**	**	**	**	**	**	
		5000	**	*	*	*	*	*	*	*	*	0.39	**	**	**	**	**	**	**	**	**	**
33"	4 1/2"	4000	**	0.18	0.14	0.14	0.15	0.20	0.24	0.30	**	**	**	**	**	**	**	**	**	**	**	
36"	4"	4000	**	0.22	0.18	0.13	0.15	0.21	0.27	0.38	**	**	**	**	**	**	**	**	**	**	**	
		5000	**	*	*	*	*	*	*	*	*	*	0.47	**	**	**	**	**	**	**	**	**
36"	4 3/4"	4000	**	0.19	0.16	0.12	0.13	0.18	0.23	0.28	**	**	**	**	**	**	**	**	**	**	**	
		5000	**	*	*	*	*	*	*	*	*	0.32	**	**	**	**	**	**	**	**	**	**
		6000	**	*	*	*	*	*	*	*	*	*	0.46	**	**	**	**	**	**	**	**	**
36"	4"	4000	0.18	0.17	0.09	0.11	0.11	0.15	0.20	0.26	0.36	**	**	**	**	**	**	**	**	**	**	
		5000	0.12	0.11	0.07	0.07	0.07	0.08	0.10	0.13	0.16	**	**	**	**	**	**	**	**	**	**	
		6000	*	*	*	*	*	*	*	*	*	0.53	**	**	**	**	**	**	**	**	**	**
36"	4 3/4"	4000	0.15	0.14	0.11	0.09	0.09	0.13	0.16	0.20	0.23	0.43	**	**	**	**	**	**	**	**	**	
		5000	0.09	0.09	0.07	0.07	0.07	0.07	0.07	0.09	0.11	0.15	**	**	**	**	**	**	**	**	**	
42"	4 1/2"	4000	0.19	0.18	0.16	0.14	0.14	0.18	0.24	0.34	0.46	**	**	**	**	**	**	**	**	**	**	
		6000	0.12	0.12	0.09	0.08	0.08	0.10	0.13	0.16	0.19	**	**	**	**	**	**	**	**	**	**	
42"	5 1/4"	4000	0.16	0.15	0.13	0.12	0.12	0.15	0.20	0.24	0.30	0.61	**	**	**	**	**	**	**	**	**	
		5000	0.10	0.09	0.08	0.07	0.07	0.07	0.09	0.12	0.14	0.20	**	**	**	**	**	**	**	**	**	
48"	5"	4000	0.19	0.19	0.18	0.16	0.16	0.21	0.29	0.42	0.56	**	**	**	**	**	**	**	**	**	**	
		6000	0.12	0.12	0.11	0.09	0.09	0.11	0.15	0.19	0.23	**	**	**	**	**	**	**	**	**	**	
48"	5 3/4"	4000	0.17	0.16	0.15	0.14	0.14	0.18	0.23	0.28	0.44	**	**	**	**	**	**	**	**	**	**	
		5000	0.10	0.10	0.09	0.07	0.07	0.09	0.11	0.14	0.17	**	**	**	**	**	**	**	**	**	**	
		6000	*	*	*	*	*	*	*	*	*	0.62	**	**	**	**	**	**	**	**	**	**
		7000	*	*	*	*	*	*	*	*	*	0.29	**	**	**	**	**	**	**	**	**	**
		8000	*	*	*	*	*	*	*	*	*	0.23	**	**	**	**	**	**	**	**	**	**

TYPE B STANDARD INSTALLATION REQUIRED FILL/COVER HEIGHT FT. / PROOF TEST LOAD (lbs./LF/FT. OF DIAMETER)																			
DIA. (In.)	15' MIN. H	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'	15' ≤ H < 20'	20' ≤ H < 25'	25' ≤ H < 30'	30' ≤ H < 40'	40' ≤ H < 50'	50' ≤ H < 60'	60' ≤ H < 70'	70' ≤ H < 80'	80' ≤ H < 90'	90' ≤ H < 100'	100' ≤ H < 110'	110' ≤ H < 120'	120' ≤ H < 130'	130' ≤ H < 140'	
12	1634	1115	923	1114	866	1213	1584	1953	2346	3118	3892	4668	5444	6220	6997	7774			
15	1470	1015	858	811	843	1182	1544	1914	2287	3040	3795	4451	5308	6065	6822	7580			
18	1342	996	802	853	827	1161	1517	1881	2248	2988	3730	4473	5217	5961	6706	7450			
21	1238	931	758	852	816	1147	1498	1857	2220	2950	3683	4418	5152	5887	6622	7358			
24	1154	881	728	868	841	1187	1553	1927	2303	3061	3822	4584	5347	6109	6872	7635			
27	1317	1004	695	860	834	1178	1541	1912	2286	3039	3794	4550	5307	6064	6821	7579			
30	1237	952	668	854	828	1171	1532	1901	2272	3020	3771	4523	5275	6028	6781	7534			
33	1168	907	640	846	823	1164	1524	1891	2261	3006	3753	4501	5249	5998	6747	7496			
36	1039	870	621	856	837	1186	1554	1929	2306	3066	3828	4591	5355	6119	6883	7648			
42	924	892	624	848	829	1178	1543	1916	2291	3046	3803	4562	5320	6079	6839	7598			
48	754	827	587	841	823	1171	1536	1906	2280	3031	3785	4539	5294	6050	6805	7561			

NOTE: THESE PROOF LOADS INCLUDE A FACTOR OF SAFETY OF 1.43 FOR FIELD CRACK CONTROL.

NOTE: PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 2.

LEGEND
 = FOR INFORMATION ONLY. PROOF LOAD TEST MUST BE PERFORMED TO THE MAXIMUM PROOF TEST LOAD FOR THE RANGE OF ITEM NUMBER.

- NOTES:
- 1) * INDICATES SAME STEEL AREA AS SHOWN FOR THE LESSER CONCRETE STRENGTH.
 - 2) ** INDICATES A SPECIAL DESIGN IS REQUIRED. USE PAIDD SOFTWARE.
 - 3) ELLIPTICAL REINFORCING IS NOT ALLOWED, EXCEPT FOR QUADRANT REINFORCEMENT AND FOR REINFORCEMENT OF ELLIPTICAL PIPE.
 - 4) FOR DOUBLE CIRCULAR STEEL REINFORCED PIPE, TWO AREAS ARE SHOWN. THE GREATER AREA IS FOR THE INNER CAGE STEEL AND LESSER AREA IS FOR OUTER CAGE STEEL.
 - 5) FOR PIPE SIZES GREATER THAN 48" DIAMETER, USE TYPE A STANDARD INSTALLATION DESIGN TABLES.
 - 6) H = DESIGN FILL HEIGHT, FT.
 - 7) SUBSTITUTION OF PIPES UNDER FILLS OF 3'-0" OR LESS IS PERMITTED ONLY WITH DESIGNER APPROVAL.
 - 8) USE PAIDD SOFTWARE ONLY FOR PIPE DESIGNS NOT PROVIDED BY BD-636M.
 - 9) STEEL AREAS SPECIFIED IN THE FILL HEIGHT / STEEL AREA TABLES ARE TO BE ACHIEVED USING ONE LAYER OF REINFORCEMENT FOR EACH CAGE. TWO LAYERS MAY BE SUBSTITUTED FOR ONE LAYER PROVIDED THE SUM OF THE STEEL AREAS OF THE 2 LAYERS IS EQUAL TO THE AREA OF STEEL FOR THE SINGLE LAYER CAGE. WHEN SUBSTITUTING, SPACING OF REINFORCEMENT IS TO REMAIN THE SAME. DESIGNING FOR 2 LAYERS OF REINFORCEMENT AND PROVIDING ONE LAYER OF REINFORCEMENT OF EQUIVALENT AREA IS NOT PERMITTED.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

DESIGN TABLES AND PROOF TEST LOAD TABLE FOR CIRCULAR PIPES
 - TYPE B STANDARD INSTALLATION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
 BUREAU OF DESIGN

STANDARD REINFORCED CONCRETE PIPES DESIGN TABLES

RECOMMENDED 6-9-10 <i>Thos. M. Macione</i> CHIEF BRIDGE ENGINEER	RECOMMENDED 6-9-10 <i>Ben. J. ...</i> DIRECTOR, BUREAU OF DESIGN	SHEET 14 OF 18 BD-636M
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TYPE A SHORING/TRENCH BOX - STEEL AREAS (in. ² /ft.)							
Dia.	Wall Thick.	f'c (psi)	Required Fill/Cover Height (mm)				
			H < 1.5'	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'
12"	2"	4000					0.08
12"	2 1/4"	4000	NO SHORING IS REQUIRED	NO SHORING IS REQUIRED			0.08
15"	2 1/4"	4000			0.09		0.08
15"	3"	4000			0.09		0.08
18"	2 1/2"	4000			0.12	0.09	0.10
18"	3 1/4"	4000			0.11	0.08	0.09
21"	2 3/4"	4000			0.14	0.11	0.13
21"	3 1/2"	4000			0.14	0.10	0.11
24"	3"	4000			0.18	0.14	0.14
24"	3 3/4"	4000			0.17	0.12	0.10
27"	4"	4000			0.17	0.14	0.16
30"	3 1/2"	4000			0.33	0.24	0.19
30"	4 1/4"	4000			0.26	0.20	0.20
33"	3 3/4"	4000			0.36	0.27	0.21
33"	4 1/2"	4000			0.30	0.23	0.18
36"	4"	4000			0.36	0.31	0.22
36"	4 3/4"	4000			0.31	0.26	0.20
36"	4"	4000			0.29	0.22	0.18
36"	4"	4000			0.16	0.12	0.09
36"	4 3/4"	4000			0.23	0.18	0.15
42"	4 1/2"	4000			0.30	0.26	0.23
42"	5 1/4"	4000			0.24	0.22	0.20
					0.13	0.11	0.10

TYPE A SHORING/TRENCH BOX - STEEL AREAS (in. ² /ft.)								
Dia.	Wall Thick.	f'c (psi)	Required Fill/Cover Height (mm)					
			H < 1.5'	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'	
48"	5"	4000	**	0.30	0.30	0.26	0.27	0.44
			**	0.16	0.16	0.13	0.13	0.16
48"	5 3/4"	4000	**	0.26	0.26	0.23	0.23	0.30
			**	0.14	0.14	0.11	0.11	0.14
54"	5 1/2"	4000	**	0.32	0.31	0.30	0.34	0.53
			**	0.17	0.16	0.15	0.15	0.18
54"	6 1/4"	4000	**	0.27	0.27	0.26	0.27	0.38
			**	0.14	0.13	0.13	0.12	0.15
60"	6"	4000	**	0.33	0.33	0.33	0.42	0.62
			**	0.18	0.17	0.17	0.17	0.20
60"	6 3/4"	4000	**	0.29	0.29	0.30	0.31	0.48
			**	0.15	0.14	0.15	0.14	0.18
66"	6 1/2"	4000	**	0.35	0.35	0.38	0.50	0.74
			**	0.18	0.18	0.18	0.19	0.23
66"	7 1/4"	4000	**	0.31	0.31	0.33	0.37	0.60
			**	0.16	0.15	0.16	0.16	0.20
72"	7"	4000	**	0.37	0.39	0.43	0.58	**
			**	0.19	0.19	0.18	0.21	**
72"	7 3/4"	4000	**	0.34	0.35	0.36	0.45	0.75
			**	0.17	0.16	0.17	0.19	0.23
78"	7 1/2"	4000	**	0.39	0.39	0.51	0.67	**
			**	0.20	0.20	0.20	0.23	**
78"	8 1/4"	4000	**	0.36	0.39	0.39	0.53	0.91
			**	0.18	0.18	0.18	0.21	0.25

TYPE A SHORING/TRENCH BOX - STEEL AREAS (in. ² /ft.)								
Dia.	Wall Thick.	f'c (psi)	Required Fill/Cover Height (mm)					
			H < 1.5'	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'	
84"	8"	4000	**	0.42	0.42	0.59	0.78	**
			**	0.21	0.21	0.22	0.26	**
		6000	**	*	*	*	*	0.90
			**	*	*	*	*	0.31
84"	8 3/4"	4000	**	0.39	0.39	0.47	0.64	**
			**	0.19	0.19	0.20	0.23	**
		5000	**	*	*	*	*	0.82
			**	*	*	*	*	0.28
90"	8 1/2"	4000	**	0.45	0.45	0.68	0.92	**
			**	0.22	0.22	0.25	0.28	**
		6000	**	*	*	*	*	1.01
			**	*	*	*	*	0.33
90"	9 1/4"	4000	**	0.41	0.41	0.55	0.93	**
			**	0.20	0.20	0.23	0.28	**
		5000	**	*	*	*	*	0.94
			**	*	*	*	*	0.30
96"	9"	4000	**	0.50	0.48	0.76	**	**
			**	0.23	0.23	0.27	**	**
		5000	**	*	*	*	0.88	**
			**	*	*	*	0.30	**
96"	9 3/4"	4000	**	0.44	0.44	0.64	0.93	**
			**	0.21	0.21	0.25	0.28	**
		6000	**	*	*	*	*	0.95
			**	*	*	*	*	0.33
102"	9 1/2"	4000	**	0.56	0.52	0.85	**	**
			**	0.25	0.25	0.30	**	**
		5000	**	*	*	*	0.97	**
			**	*	*	*	0.33	**
102"	10 1/4"	4000	**	0.47	0.48	0.73	**	**
			**	0.23	0.23	0.27	**	**
		5000	**	*	*	*	0.83	**
			**	*	*	*	0.30	**

TYPE A S/T BOX - STEEL AREAS (in. ² /ft.)								
Dia.	Wall Thick.	f'c (psi)	Required Fill/Cover Height (mm)					
			H < 1.5'	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'	
108"	10"	4000	**	0.62	0.58	**	**	**
			**	0.26	0.26	*	*	**
		6000	**	*	*	*	*	1.00
			**	*	*	*	*	0.35
108"	10 3/4"	4000	**	0.51	0.51	0.86	**	**
			**	0.24	0.24	0.30	**	**
		5000	**	*	*	*	0.93	**
			**	*	*	*	0.33	**
114"	10 1/2"	4000	**	0.68	0.65	**	**	**
			**	0.28	0.28	*	**	**
		6000	**	*	*	*	1.11	**
			**	*	*	*	0.38	**
114"	11 1/4"	4000	**	0.58	0.55	0.73	**	**
			**	0.26	0.26	0.29	**	**
		5000	**	*	*	*	1.06	**
			**	*	*	*	0.35	**
120"	11"	4000	**	0.75	**	**	**	**
			**	0.29	**	**	**	**
		5000	**	*	0.72	*	**	**
			**	*	0.30	*	**	**
120"	11 3/4"	4000	**	0.64	0.62	0.82	**	**
			**	0.28	0.28	0.31	**	**
		6000	**	*	*	*	1.07	**
			**	*	*	*	0.38	**

TYPE A SHORING/TRENCH BOX INSTALLATION REQUIRED FILL/COVER HEIGHT (FT.) / PROOF TEST LOAD (lbs/LF/FT. OF DIAMETER)									
DIA. (in.)	Required Fill/Cover Height (ft.)								
	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'	10' ≤ H < 15'	15' ≤ H < 20'	20' ≤ H < 25'		
12	1762	1496	1196	1298	1818	2376	2945		
15	1621	1393	1155	1260	1772	2318	2872		
18	1509	1313	1087	1237	1741	2276	2822		
21	1418	1247	1048	1220	1719	2247	2787		
24	1341	1192	1015	1207	1702	2226	2761		
27	1274	1143	986	1196	1888	2209	2740		
30	1216	1101	961	1187	1878	2195	2723		
33	1165	1063	938	1180	1869	2184	2710		
36	1119	1029	924	1174	1861	2175	2698		
42	1092	985	1105	1467	2105	2767	3439		
48	1023	936	1114	1457	2093	2753	3422		
54	1015	895	1104	1449	2084	2742	3409		
60	961	858	1096	1442	2077	2733	3398		
66	965	858	1089	1436	2070	2726	3389		
72	922	829	1082	1431	2065	2719	3382		
78	882	802	1076	1426	2061	2714	3375		
84	847	778	1071	1422	2057	2709	3370		
90	786	786	1066	1418	2053	2705	3365		
96	752	752	1061	1415	2050	2702	3361		
102	753	712	1057	1412	2047	2699	3357		
108	705	678	1053	1409	2044	2696	3354		
114	671	671	1049	1406	2042	2693	3351		
120	643	643	1046	1404	2040	2691	3348		

NOTE: THESE PROOF LOADS INCLUDE A 1.43 SAFETY FACTOR FOR FIELD CRACK CONTROL.

NOTE 1: PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 2.

DESIGN TABLES AND PROOF TEST LOAD TABLE FOR CIRCULAR PIPES - TYPE A SHORING/TRENCH BOX INSTALLATION

- NOTES:
- * INDICATES SAME STEEL AREA AS SHOWN FOR THE LESSER CONCRETE STRENGTH.
 - ** INDICATES A SPECIAL DESIGN IS REQUIRED. USE PAIDD SOFTWARE.
 - ELLIPTICAL REINFORCING IS NOT ALLOWED, EXCEPT FOR QUADRANT REINFORCEMENT AND REINFORCEMENT OF ELLIPTICAL PIPE.
 - FOR DOUBLE CIRCULAR STEEL REINFORCED PIPE, TWO AREAS ARE SHOWN. THE GREATER AREA IS FOR THE INNER CAGE STEEL AND LESSER AREA IS FOR OUTER CAGE STEEL.
 - FOR PIPE DIAMETERS GREATER THAN 48", USE TYPE A SHORING/TRENCH BOX DESIGN TABLES.
 - FOR FILL HEIGHTS GREATER THAN INDICATED, USE THE PAIDD PROGRAM.
 - H = DESIGN FILL HEIGHT, FT.
 - SUBSTITUTION OF PIPES UNDER FILLS OF 3'-0" OR LESS IS PERMITTED ONLY WITH DESIGNER APPROVAL.
 - USE PAIDD SOFTWARE ONLY FOR PIPE DESIGNS NOT PROVIDED BY BD-636M.
 - STEEL AREAS SPECIFIED IN THE FILL HEIGHT / STEEL AREA TABLES ARE TO BE ACHIEVED USING ONE LAYER OF REINFORCEMENT FOR EACH CAGE. TWO LAYERS MAY BE SUBSTITUTED FOR ONE LAYER PROVIDED THE SUM OF THE STEEL AREAS OF THE 2 LAYERS IS EQUAL TO THE AREA OF STEEL FOR THE SINGLE LAYER CAGE. WHEN SUBSTITUTING, SPACING OF REINFORCEMENT IS TO REMAIN THE SAME. DESIGNING FOR 2 LAYERS OF REINFORCEMENT AND PROVIDING ONE LAYER OF REINFORCEMENT OF EQUIVALENT AREA IS NOT PERMITTED.

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

TYPE B SHORING/TRENCH BOX - STEEL AREAS (in. ² /ft.)							
Dia.	Wall Thick.	f'c (psi)	Required Fill/Cover Height (mm)				
			H < 1.5'	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'
12"	2"	4000					0.08
12"	2 1/4"	4000	NO SHORING IS REQUIRED	NO SHORING IS REQUIRED			0.07
15"	2 1/4"	4000					0.08
15"	3"	4000					0.07
18"	2 1/2"	4000			0.11	0.09	0.07
18"	3 1/4"	4000			0.09	0.07	0.07
21"	2 3/4"	4000			0.13	0.11	0.09
21"	3 1/2"	4000			0.11	0.09	0.09
24"	3"	4000			0.16	0.13	0.11
24"	3 3/4"	4000			0.13	0.11	0.11
27"	3 3/4"	4000			0.19	0.15	0.13
27"	4"	4000			0.16	0.13	0.11
30"	3 1/2"	4000	**	0.29	0.22	0.17	0.15
30"	4 1/4"	4000	**	0.25	0.18	0.15	0.13
33"	3 3/4"	4000	**	0.33	0.25	0.20	0.17
33"	4 1/2"	4000	**	0.28	0.21	0.17	0.15

TYPE B SHORING/TRENCH BOX - STEEL AREAS (in. ² /ft.)								
Dia.	Wall Thick.	f'c (psi)	Required Fill/Cover Height (mm)					
			H < 1.5'	1.5' ≤ H < 2'	2' ≤ H < 3'	3' ≤ H < 4'	4' ≤ H < 10'	
36"	4"	4000	**	0.35	0.27	0.21	0.20	0.30
36"	4 3/4"	4000	**	0.29	0.24	0.19	0.17	0.24
36"	4"	4000	**	0.27	0.21	0.17	0.15	0.18
			**	0.15	0.07	0.08	0.07	0.08
36"	4 3/4"	4000	**	0.22	0.17	0.14	0.13	0.15
			**	0.12	0.09	0.07	0.07	0.07
42"	4 1/2"	4000	**	0.28	0.24	0.22	0.22	0.33

TYPE A STANDARD INSTALLATION HORIZONTAL ELLIPTICAL PIPE H<1.5 ft				
Equi- valent Round	Rise /Span (in.)	Wall Thick. (in.)	f' c (psi)	Steel Area (in. ² /ft.)
18"	14x23	2 3/4"	4000	**
			5000	0.20
24"	19x30	3 1/4"	4000	**
27"	22x34	3 1/2"	4000	**
			5000	**
			6000	**
30"	24x38	3 3/4"	4000	0.22
				0.22
33"	27x42	3 3/4"	4000	0.25
				0.25
36"	29x45	4 1/2"	4000	0.21
				0.21
42"	34x53	5"	4000	0.23
				0.23
48"	38x60	5 1/2"	4000	0.24
				0.24
54"	43x68	6"	4000	0.26
				0.26
60"	48x76	6 1/2"	4000	0.28
				0.28
66"	53x83	7"	4000	0.30
				0.30
72"	58x91	7 1/2"	4000	0.33
				0.33
78"	63x98	8"	4000	0.36
				0.36
84"	68x106	8 1/2"	4000	0.44
				0.44
90"	72x113	9"	4000	0.50
				0.50
96"	77x121	9 1/2"	4000	0.60
				0.60
102"	82x128	9 3/4"	4000	0.71
				0.71
108"	87x136	10"	4000	0.86
				0.86
114"	92x143	10 1/2"	4000	0.95
				0.95
120"	97x151	11"	4000	1.08
				1.08

TYPE B STANDARD INSTALLATION HORIZONTAL ELLIPTICAL PIPE H<1.5 ft.				
Equi- valent Round	Rise /Span (in.)	Wall Thick. (in.)	f' c (psi)	Steel Area (in. ² /ft.)
18"	14x23	2 3/4"	4000	0.20
24"	19x30	3 1/4"	4000	**
			5000	**
			6000	0.29
27"	22x34	3 1/2"	4000	**
			5000	**
			6000	**
30"	24x38	3 3/4"	4000	0.21
				0.21
33"	27x42	3 3/4"	4000	0.23
				0.23
36"	29x45	4 1/2"	4000	0.20
				0.20
42"	34x53	5"	4000	0.22
				0.22
48"	38x60	5 1/2"	4000	0.23
				0.23
54"	43x68	6"	4000	0.25
				0.25
60"	48x76	6 1/2"	4000	0.27
				0.27
66"	53x83	7"	4000	0.29
				0.29
72"	58x91	7 1/2"	4000	0.32
				0.32
78"	63x98	8"	4000	0.34
				0.34
84"	68x106	8 1/2"	4000	0.42
				0.42
90"	72x113	9"	4000	0.47
				0.47
96"	77x121	9 1/2"	4000	0.56
				0.56
102"	82x128	9 3/4"	4000	0.71
				0.71
108"	87x136	10"	4000	0.82
				0.82
114"	92x143	10 1/2"	4000	0.90
				0.90
120"	97x151	11"	4000	1.02
				1.02

NOTES:

- 1) * INDICATES SAME STEEL AREA AS SHOWN FOR THE LESSER CONCRETE STRENGTH.
- 2) ** INDICATES A SPECIAL DESIGN IS REQUIRED. USE PAIDD SOFTWARE.
- 3) ELLIPTICAL REINFORCING IS NOT ALLOWED, EXCEPT FOR QUADRANT REINFORCEMENT AND REINFORCEMENT OF ELLIPTICAL PIPE.
- 4) FOR DOUBLE CIRCULAR STEEL REINFORCED PIPE, TWO AREAS ARE SHOWN. THE GREATER AREA IS FOR THE INNER CAGE STEEL AND LESSER AREA IS FOR OUTER CAGE STEEL.
- 5) *** INDICATES A SHEAR CONTROL HAS BEEN REACHED. USE PAIDD SOFTWARE FOR SPECIAL DESIGN.
- 6) H = DESIGN FILL HEIGHT, FT.
- 7) SUBSTITUTION OF PIPES UNDER FILLS OF 3'-0" OR LESS IS PERMITTED ONLY WITH DESIGNER APPROVAL.
- 8) FOR DESIGN OF A TYPE A STANDARD ELLIPTICAL PIPE FOLLOW THESE STEPS:
 - (a) SELECT THE LARGER DIMENSION OF SPAN OR RISE FROM ELLIPTICAL PIPE SIZES SHOWN IN THE TYPE A SHORING/TRENCH BOX TABLE FOR ELLIPTICAL PIPES.
 1. E. RISE DIMENSION FOR VERTICAL ELLIPTICAL
 - SPAN DIMENSION FOR HORIZONTAL ELLIPTICAL
 - (b) GO TO TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPES.
 - (c) USE THE RISE DIMENSION FOR VERTICAL ELLIPTICAL DESIGNS OR THE SPAN DIMENSION FOR THE HORIZONTAL ELLIPTICAL DESIGNS AS THE DIAMETER IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPE. [IF THE SELECTED DIAMETER IS NOT AVAILABLE IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPE, USE THE NEXT LARGER AVAILABLE DIAMETER IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPE TO DETERMINE THE STEEL AREA.]
 - (d) FOR THE SELECTED DIAMETER, WALL THICKNESS, DESIGN FILL HEIGHT AND CONCRETE STRENGTH, DETERMINE THE AREA OF STEEL REQUIRED FOR THE INNER CAGE OF THE PIPE IN THE TYPE A STANDARD INSTALLATION TABLES FOR CIRCULAR PIPES. USE THIS AREA FOR EACH, INNER AND OUTER, CAGE FOR THE ELLIPTICAL PIPE DESIGN.
- 9) USE PAIDD SOFTWARE ONLY FOR PIPE DESIGNS NOT PROVIDED BY BD-636M.
- 10) STEEL AREAS SPECIFIED IN THE FILL HEIGHT / STEEL AREA TABLES ARE TO BE ACHIEVED USING ONE LAYER OF REINFORCEMENT FOR EACH CAGE. TWO LAYERS MAY BE SUBSTITUTED FOR ONE LAYER PROVIDED THE SUM OF THE STEEL AREAS OF THE 2 LAYERS IS EQUAL TO THE AREA OF STEEL FOR THE SINGLE LAYER CAGE. WHEN SUBSTITUTING, SPACING OF REINFORCEMENT IS TO REMAIN THE SAME. DESIGNING FOR 2 LAYERS OF REINFORCEMENT AND PROVIDING ONE LAYER OF REINFORCEMENT OF EQUIVALENT AREA IS NOT PERMITTED.

DESIGN TABLES FOR HORIZONTAL ELLIPTICAL PIPE-STANDARD INSTALLATION- TYPE A / TYPE B

NOTE: EITHER ALL METRIC OR ALL ENGLISH VALUES MUST BE USED ON PLANS. METRIC AND ENGLISH VALUES SHOWN MAY NOT BE MIXED.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
 BUREAU OF DESIGN

STANDARD
 REINFORCED CONCRETE PIPES
 ELLIPTICAL PIPE DESIGN TABLES

RECOMMENDED 6-9-10
Thos. Macione
 CHIEF BRIDGE ENGINEER

RECOMMENDED 6-9-10
Bruce Shyne
 DIRECTOR, BUREAU OF DESIGN

SHEET 16 OF 18
 BD-636M

TYPE B SHORING/TRENCH BOX VERTICAL ELLIPTICAL PIPE - STEEL AREAS (in ² /ft.)														
Equivalent Round (In.)	Rise/Span (In.)	Wall Thick. (In.)	f'c (psi)	Required Fill/Cover Height (mm)										
				H < 1.5'	1.5' < H < 2'	2' < H < 3'	3' < H < 4'	4' < H < 10'	15'	20'	25'			
36"	45/29	4 1/2"	4000	**	0.22	0.18	0.13	0.11	0.16	0.20	0.25			
42"	53/34	5"	4000	**	0.13	0.11	0.08	0.07	0.11	0.14	0.17	0.20	0.25	0.32
48"	60/38	5 1/2"	4000	**	0.16	0.13	0.10	0.07	0.11	0.14	0.20	0.26	0.39	
54"	68/43	6"	4000	**	0.10	0.09	0.07	0.07	0.10	0.13	0.20	0.26	0.52	
60"	76/48	6 1/2"	4000	**	0.20	0.20	0.17	0.17	0.23	0.30	0.52			
66"	83/53	7"	4000	**	0.10	0.10	0.08	0.07	0.12	0.15	0.26			
72"	91/58	7 1/2"	4000	**	0.21	0.21	0.19	0.19	0.27	0.38	0.67			
78"	98/63	8"	4000	**	0.11	0.10	0.09	0.08	0.14	0.16	0.34			
84"	106/68	8 1/2"	4000	**	0.22	0.22	0.21	0.22	0.30	0.49	**			
90"	113/72	9"	4000	**	0.11	0.11	0.10	0.10	0.15	0.25	**			
96"	121/77	9 1/2"	4000	**	**	**	**	**	**	0.61	**			
102"	128/82	9 3/4"	4000	**	**	**	**	**	**	0.74	**			
108"	136/87	10"	4000	**	**	**	**	**	**	0.37	**			
114"	143/92	10 1/2"	4000	**	0.25	0.25	0.26	0.28	0.40	0.75	**			
120"	151/97	11"	4000	**	0.12	0.12	0.12	0.12	0.20	0.38	**			
		5000	**	**	**	**	**	**	**	0.71	**			
		6000	**	**	**	**	**	**	**	0.81	**			
84"	106/68	8 1/2"	4000	**	0.26	0.26	0.27	0.31	0.46	**	**			
		5000	**	0.13	0.13	0.13	0.14	0.23	**	**	**			
		6000	**	**	**	**	**	**	**	0.32	**			
		5000	**	**	**	**	**	**	**	0.81	**			
		6000	**	**	**	**	**	**	**	0.42	**			
90"	113/72	9"	4000	**	0.27	0.27	0.29	0.33	0.51	**	**			
		5000	**	0.13	0.13	0.13	0.15	0.26	**	**	**			
		6000	**	**	**	**	**	**	**	0.71	**			
96"	121/77	9 1/2"	4000	**	0.29	0.29	0.31	0.36	0.62	**	**			
		5000	**	0.14	0.14	0.14	0.16	0.31	**	**	**			
		6000	**	**	**	**	**	**	**	0.83	**			
102"	128/82	9 3/4"	4000	**	0.31	0.32	0.35	0.40	0.79	**	**			
		5000	**	0.15	0.15	0.15	0.18	0.40	**	**	**			
		6000	**	**	**	**	**	**	**	0.83	**			
108"	136/87	10"	4000	**	0.34	0.34	0.38	0.46	**	**	**			
		5000	**	0.16	0.16	0.17	0.20	**	**	**	**			
		6000	**	**	**	**	**	**	**	0.72	**			
114"	143/92	10 1/2"	4000	**	0.36	0.36	0.42	0.52	**	**	**			
		5000	**	0.17	0.17	0.19	0.22	**	**	**	**			
		6000	**	**	**	**	**	**	**	0.80	**			
120"	151/97	11"	4000	**	0.38	0.39	0.45	0.58	**	**	**			
		5000	**	0.18	0.18	0.20	0.23	**	**	**	**			
		6000	**	**	**	**	**	**	**	0.90	**			
		5000	**	**	**	**	**	**	**	0.45	**			

PROOF TEST LOAD TABLE FOR VERTICAL ELLIPTICAL PIPE TYPE B SHORING/TRENCH - BOX INSTALLATION (lbs/ft. of DIAMETER)														
Equivalent Round (In.)	Rise/Span (In.)	Wall Thick. (In.)	f'c (psi)	REQUIRED FILL/COVER HEIGHT (FT.) / PROOF TEST LOADS										
				H < 1.5'	1.5' < H < 2'	2' < H < 3'	3' < H < 4'	4' < H < 10'	15'	20'	25'			
36	45x29	4 1/2"	4000	957	901	877	1122	1594	2088	2591				
42	53x34	5"	4000	884	845	863	1110	1579	2070	2559				
48	60x38	5 1/2"	4000	874	822	1057	1391	2004	2638	3230				
54	68x43	6"	4000	821	782	1046	1382	1993	2624	3253				
60	76x48	6 1/2"	4000	775	748	1037	1373	1984	2613	3250				
66	83x53	7"	4000	771	720	1029	1366	1976	2604	3239				
72	91x58	7 1/2"	4000	736	694	1021	1360	1970	2596	3230				
78	98x63	8"	4000	739	695	1015	1355	1964	2590	3222				
84	106x68	8 1/2"	4000	710	674	1009	1350	1960	2584	3215				
90	113x72	9"	4000	689	659	1005	1347	1956	2580	3211				
96	121x77	9 1/2"	4000	666	642	1000	1343	1952	2576	3206				
102	128x82	9 3/4"	4000	644	627	995	1340	1949	2572	3201				
108	136x87	10"	4000	633	633	991	1336	1946	2569	3197				
114	143x92	10 1/2"	4000	619	619	987	1333	1943	2566	3193				
120	151x97	11"	4000	599	595	984	1331	1940	2563	3190				

NOTE: PROOF LOADS ARE AN INDICATION OF CRACK CONTROLS AND NOT NECESSARILY STRENGTH CONTROL. ACTUAL STRUCTURAL DESIGN (CONCRETE STRENGTH, AREA OF STEEL AND WALL THICKNESS) IS BASED UPON FLEXURE, CRACKING, OR SHEAR - WHICHEVER GOVERNS. FOR SUBSTITUTION OF PIPES RELY UPON THE MAXIMUM VS. MINIMUM FILL HEIGHT STAMP. DO NOT USE THE PROOF LOAD FOR SUBSTITUTION PURPOSES. SEE FIGURE "FLEXURE - SHEAR - CRACK CONTROL" AND EXAMPLE ON SHEET 2.

TYPE B SHORING/TRENCH BOX HORIZONTAL ELLIPTICAL PIPE - STEEL AREAS (in ² /ft.)														
Equivalent Round (In.)	Rise/Span (In.)	Wall Thick. (In.)	f'c (psi)	Required Fill/Cover Height (mm)										
				H < 1.5'	1.5' < H < 2'	2' < H < 3'	3' < H < 4'	4' < H < 10'	15'	20'	25'			
18"	14x23	2 3/4"	4000	**	0.22	0.18	0.13	0.12						
24"	19x30	3 1/4"	4000	**	0.32	0.25	0.19	0.17						
27"	22x34	3 1/2"	4000	**	0.38	0.31	0.23	0.21						
30"	24x38	3 3/4"	4000	**	0.34	0.27	0.22	0.26						
33"	27x42	3 3/4"	4000	**	0.34	0.27	0.22	0.26						
36"	29x45	4 1/4"	4000	**	0.37	0.33	0.27	0.38						
42"	34x53	5"	4000	**	0.37	0.33	0.32	0.43						
48"	38x60	5 1/2"	4000	**	0.37	0.37	0.40	0.53						
54"	43x68	6"	4000	**	0.43	0.43	0.51	0.67						
60"	48x76	6 1/2"	4000	**	0.43	0.43	0.51	0.67						
66"	53x83	7"	4000	**	0.51	0.51	0.63	0.82						
72"	58x91	7 1/2"	4000	**	0.51	0.51	0.63	0.82						
78"	63x98	8"	4000	**	0.57	0.57	0.73	0.89						
84"	68x106	8 1/2"	4000	**	0.57	0.57	0.73	0.89						
90"	72x113	9"	4000	**	0.67	0.67	0.87	1.03						
96"	77x121	9 1/2"	4000	**	0.67	0.67	0.87	1.03						
102"	82x128	9 3/4"	5000	**	0.74	0.74	**	**						
108"	87x136	10"	5000	**	0.74	0.74	**	**						
114"	92x143	10 1/2"	5000	**	**	**	0.93	**						
120"	97x151	11"	4000	**	**	**	0.93	**						
		5000	**	**	**	**	1.10	**						
		6000	**	**	**	**	1.10	**						
90"	113/72	9"	4000	**	0.85	0.85	**	**						
		5000	**	0.85	0.85	**	**	**						
		6000	**	**	**	**	1.08	**						
96"	121/77	9 1/2"	4000	**	0.94	0.94	**	**						
		5000	**	0.94	0.94	**	**	**						
		6000	**	**	**	**	1.14	**						
102"	128/82	9 3/4"	4000	**	1.06	1.06	**	**						
		5000	**	1.06	1.06	**	**	**						
		6000	**	**	**	**	1.30	**						
108"	136/87	10"	4000	**	1.14	1.14	**	**						
		5000	**	1.14	1.14	**	**	**						
114"	143/92	10 1/2"	4000	**	1.33	1.33	**	**						
		5000	**	1.33	1.33	**	**	**						
120"	151/97	11"	4000	**	1.44	1.44	**	**						
		5000	**	1.44	1.44	**	**	**						
		6000	**	**	**	**	**	**						

PROOF TEST LOAD TABLE FOR HORIZONTAL ELLIPTICAL PIPE TYPE B SHORING/TRENCH - BOX INSTALLATION (lbs/ft. of DIAMETER)														
Equivalent Round (In.)	Rise/Span (In.)	Wall Thick. (In.)	f'c (psi)	REQUIRED FILL/COVER HEIGHT (FT.) / PROOF TEST LOADS										
				H < 1.5'	1.5' < H < 2'	2' < H < 3'	3' < H < 4'	4' < H < 10'	15'	20'	25'			
18	14x23	2 3/4"	4000	1515	1296	1050	1155	1624	2122	2631				
24	19x30	3 1/4"	4000	1375	1198	994	1134	1596	2087	2588				
27	22x34	3 1/2"	4000	1310	1152	968	1125	1586	2073	2571				
30	24x38	3 3/4"	4000	1319	1126	1091	1408	2011	2642	3282				
33	27x42	3 3/4"	4000	1265	1089	1084	1401	2003	2631	3268				
36	29x45	4 1/4"	4000	1228	1064	1079	1396	1997	2624	3260				
42	34x53	5"	4000	1205	1006	1068	1386	1985	2608	3241				
48	38x60	5 1/2"	4000	1138	962	1060	1379	1977	2599	3229				
54	43x68	6"	4000	1134	957	1052	1372	1969	2590	3218				
60	48x76	6 1/2"	4000	1073	917	1045	1367	1963	2582	3210				
66	53x83	7"	4000	1026	887	1039	1362	1959	2577	3204				
72	58x91	7 1/2"	4000	921	892	1034	1358	1955	2572	3198				