Stanton Bonna

Structural Design Tables For Elliptical Pipes

PD 26 REV D 21/9/05

1. Foreword

This document details a method for the structural design of Stanton Bonna Elliptical pipes for the common conditions of installation.

The procedure is based on the Marston method, which has been used for the design of rigid pipes for many years.

The information contained within the document, which includes dimensions, external load tables and bedding classes, will enable a structural design for a Elliptical pipeline to be completed.

The tables have been compiled assuming normal conditions and it may be possible to achieve a more efficient design using data more representative of the installation in question.

The tables are not applicable to all circumstances and designers are recommended to consult ref 1 for further information.

For low depths of cover ie less than 0.6 m reference should be made directly to Stanton Bonna. Although following the same basic principle for depths of cover in excess of 0.6 m it differs in the analysis of the vehicle loads.

The reader's attention is brought to the notes in section 7 and in addition the following:

(i) This document is subject to periodic revision. Please check with Stanton Bonna that you have the latest version.

(ii) This document is only applicable to Stanton Bonna Elliptical Pipes. It must not be used in connection with any other type of product manufactured by Stanton Bonna or others.

(iii) Users should ensure that the design is entrusted to persons who are suitably qualified and experienced.

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2. Pipe Dimensions

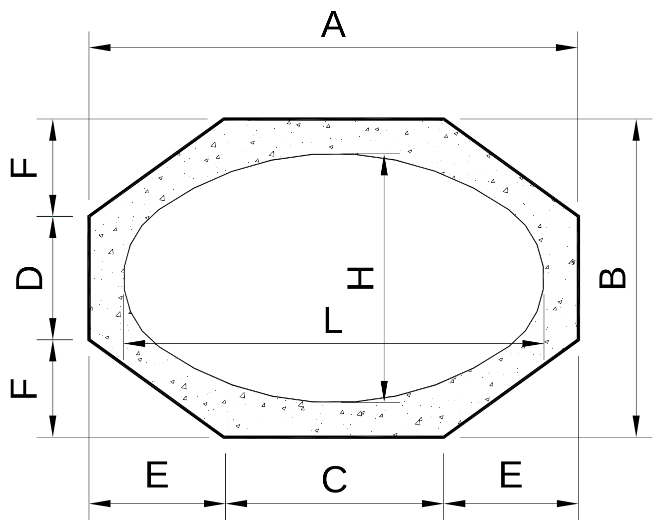


Fig 1

L x H (mm)	A x B (mm)	C (mm)	D (mm)	E (mm)	F (mm)	Wall (mm)
1000 x 650	1250 x 900	520	370	365	265	125
1150 x 750	1400 x 1000	600	430	400	285	125
1650 x 1000	1930 x 1280	850	500	540	390	140
1950 x 1150	2270 x 1470	1020	570	625	450	160
2350 x 1350	2710 x 1710	1230	670	740	520	180
2650 x 1500	3050 x 1900	1450	740	800	580	200

Table 1: Pipe Dimensions

3. Design Data

3.1 General

The methods used in the compilation of this data are based on the design principles given in ref 1.

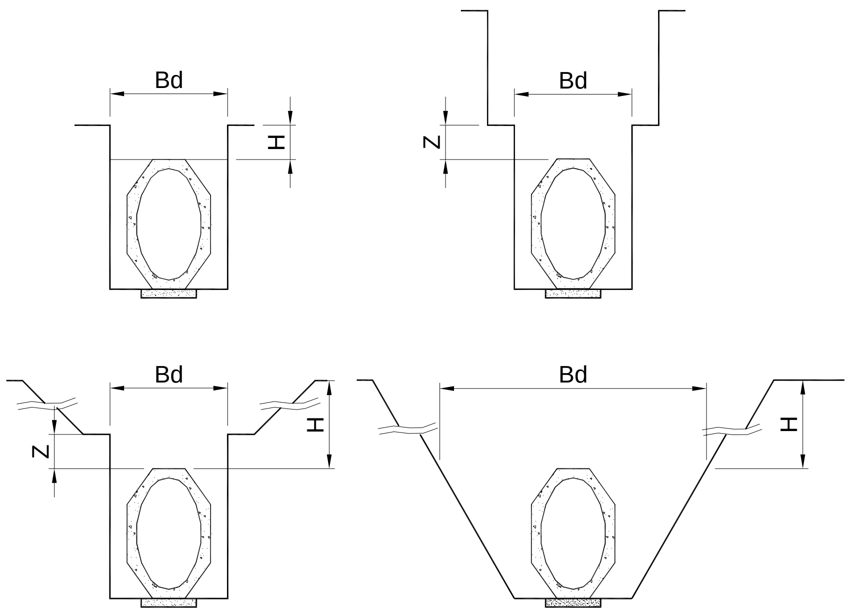
3.2 Installation Conditions

The fill load tables give external loads on Elliptical pipes laid in:

a) Narrow Trench : A trench of less than a specified width in natural ground which is subsequently backfilled (see fig 2).

b) Wide Trench : A trench of greater than a specified width in natural ground or on the surface of ground over which an embankment is subsequently constructed.

The tables do not cover situations where pipes are installed in a trench in ground over which an embankment is subsequently built. Refer to ref 1 for information on these circumstances.



For a stepped trench Z ≥ 300 mm

Fig 2: Narrow trench conditions

Elliptical Pipe	Max Trench Width (m)
1000 x 650 Vert	1.70
1150 x 750 Vert	1.80
1650 x 1000 Vert	2.10
1950 x 1150 Vert	2.25
2350 x 1350 Vert	2.50
2650 x 1500 Vert	2.70
1000 x 650 Horiz	1.85
1150 x 750 Horiz	2.00
1650 x 1000 Horiz	2.75
1950 x 1150 Horiz	3.05
2350 x 1350 Horiz	3.50
2650 x 1500 Horiz	3.85

Table 2: Recommended Maximum Trench Widths

The trench width (B_d) should not be wider than the value used in the design and should not be narrower than that required to place and compact bedding and backfill materials.

3.3 Fill Loads in Narrow Trench

Fill load in narrow trench is given by the formula

$$W_c = \frac{1 - e^{-2k\mu' H/Bd}}{2K\mu'} \gamma B_d^2 \text{ .... (1)}$$

Where	W_c	=	Fill load on pipe in kN/m.
	$K\mu'$	=	Empirical soil coefficient. (0.13)
	H	=	Height of fill above crown of pipe n m.
	B_d	=	Narrow trench width in m, see fig 2 and table 2.
	γ	=	Soil density in kN/m^3. (19.6)

3.4 Fill Loads in Wide Trench Conditions

Fill loads in wide trench conditions are given by the formulae

a) 'Complete projection'

$$W_c' = \frac{e^{2K\mu H/Bc} - 1}{2K\mu} \gamma B_c^2 \text{ .... (2)}$$

b) 'Incomplete projection'

$$W_c' = (1.59H/B_c - 0.09) \gamma B_c^2 \text{ ....(3)}$$

Where	W_c	=	Fill load on pipe in kN/m.
	$K\mu'$	=	Empirical soil coefficient. (0.19)
	H	=	Height of fill above crown of pipe m.
	B_d	=	Plan width of pipe in m.
	γ	=	Soil density in kN/m^3. (19.6)

For definitions of the terms 'complete' and 'incomplete projection' refer to ref 1.

Soil coefficients for a range of ground conditions are given in ref 4.

Equations (1), (2) and (3) are taken from ref 1.

3.5 Fill Load Tables

Fill loads for narrow trench conditions are given in table 3. The loads are the lowest of the values given by equations (1), (2) and (3).

Fill loads for wide trench conditions are given in table 4. The loads are the lower of the values given by equations (2) and (3).

In compiling the tables Kμ' and Kμ have been taken as 0.13 and 0.19 respectively. Soil density has been taken as 19.6 kN/m^3.

For narrow trench design using the tables, table 3 may be used for trench widths up to and including the values specified in table 2. For wider trench widths the fill loads given in table 4 should be used.

3.6 Vehicle Loads

Vehicle loads at depths of between 0.6 and 10 m are given as vertical pressures in table 5. Values are given for the following types of load:

a) HB 45 : As defined in BS 5400: Part 2: 1978. 8 no. 112.5 kN wheel loads (inclusive of impact allowance) arranged in two axles at 1.8 m centres each of 4 wheels. Each wheel positioned at 1 m centres on its axle.

b) Field loading : 2 no. 60 kN wheel loads at 0.9 m centres inclusive of impact factor of 2.0.

Pressures at depth are calculated by the summation of pressures from individual wheels using the Boussinesq equation. Wheel loads are assumed to act as point loads.

Note that the values in the table are pressures in kN/m^2 and it is necessary to multiply them by the plan width of the pipe to obtain design loads on the pipe in kN/m.

Loading from construction plant can exceed the loadings above and where such trafficking is expected the loading should be evaluated and the design checked accordingly.

3.7 Water Loads

Table 6 gives water loads as an external load that produces bending moments in the pipe equivalent to those due to the contained water when the pipe is running full.

Table 3 :		FILL LOADS FOR NARROW TRENCH CONDITIONS IN kN/m											
Depth to	Size	1000 x 650		1150 x 750		1650 x 1000		1950 x 1150		2350 x 1350		2650 x 1500	
Crown	Position	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz
(m)	Bd=	1.70	1.85	1.80	2.00	2.10	2.75	2.20	3.05	2.50	3.50	2.70	3.85
0.60		12.0	16.1	13.2	17.9	16.5	24.1	18.7	28.1	21.5	33.2	23.7	37.2
0.70		14.4	19.1	15.7	21.2	19.5	28.4	22.1	33.0	25.4	39.1	28.0	43.7
0.80		16.8	22.2	18.3	24.5	22.7	32.8	25.6	38.1	29.3	45.0	32.3	50.3
0.90		19.3	25.4	21.0	28.0	25.9	37.2	29.2	43.2	33.4	51.0	36.7	56.9
1.00		21.9	28.6	23.8	31.5	29.2	41.8	32.9	48.4	37.5	57.0	41.2	63.7
1.10		24.7	32.0	26.8	35.2	32.6	46.5	36.7	53.7	41.8	63.2	45.8	70.5
1.20		27.6	35.5	29.8	38.9	36.2	51.2	40.5	59.1	46.1	69.4	50.5	77.4
1.30		30.6	39.1	33.0	42.8	39.8	56.0	44.5	64.6	50.5	75.7	55.3	84.4
1.40		33.7	42.8	36.2	46.7	43.5	61.0	48.6	70.2	55.0	82.2	60.2	91.4
1.50		36.9	46.6	39.6	50.8	47.4	66.0	52.8	75.9	59.7	88.7	65.1	98.6
1.60		40.3	50.5	43.2	55.0	51.4	71.1	57.1	81.6	64.4	95.3	70.2	105.8
1.70		43.9	54.5	46.8	59.3	55.5	76.4	61.5	87.5	69.2	102.0	75.4	113.2
1.80		47.6	57.7	50.6	62.9	59.7	81.7	66.0	93.5	74.2	108.8	80.7	120.6
1.90		51.4	60.5	54.6	66.0	64.0	87.2	70.7	99.5	79.2	115.6	86.1	128.2
2.00		54.7	63.2	58.7	69.0	68.5	92.7	75.5	105.7	84.4	122.6	91.6	135.8
2.20		60.3	68.6	66.5	75.0	77.9	104.2	85.4	118.3	95.1	136.9	102.9	151.3
2.40		65.9	73.9	71.6	80.8	85.5	115.7	92.4	129.7	104.1	150.8	113.4	167.2
2.60		71.5	79.0	76.5	86.5	91.5	124.2	99.0	139.4	111.6	162.2	121.7	179.9
2.80		75.9	83.9	81.2	92.0	97.4	132.6	105.5	148.9	119.0	173.4	129.9	192.5
3.00		80.2	88.8	85.9	97.4	103.1	140.8	111.8	158.2	126.3	184.5	137.9	204.9
3.20		84.3	93.4	90.4	102.6	108.8	148.8	118.0	167.4	133.4	195.4	145.7	217.2
3.40		88.3	98.0	94.8	107.7	114.2	156.7	124.0	176.4	140.3	206.1	153.4	229.2
3.60		92.2	102.4	99.0	112.7	119.6	164.5	129.9	185.3	147.1	216.7	161.0	241.2
3.80		96.0	106.8	103.2	117.5	124.8	172.1	135.6	194.0	153.8	227.1	168.4	252.9
4.00		99.7	110.9	107.2	122.3	129.8	179.5	141.2	202.6	160.3	237.4	175.7	264.5
4.50		108.4	120.9	116.7	133.5	142.0	197.6	154.7	223.4	176.1	262.4	193.3	292.8
5.00		116.5	130.2	125.6	144.1	153.4	214.8	167.5	243.4	191.0	286.5	210.0	320.2
5.50		123.9	138.9	133.9	154.0	164.2	231.2	179.5	262.5	205.2	309.7	226.0	346.7
6.00		130.8	147.0	141.6	163.3	174.3	246.8	190.9	280.8	218.7	332.1	241.2	372.3
6.50		137.2	154.5	148.7	172.0	183.8	261.7	201.6	298.3	231.5	353.7	255.7	397.0
7.00		143.2	161.5	155.4	180.2	192.7	276.0	211.7	315.1	243.6	374.4	269.5	420.9
8.00		153.8	174.2	167.3	195.0	209.0	302.5	230.2	346.7	266.1	413.8	295.2	466.4
9.00		162.9	185.2	177.7	208.0	223.4	326.6	246.7	375.7	286.4	450.2	318.5	508.9
10.00		170.7	194.7	186.6	219.4	236.1	348.6	261.5	402.3	304.6	484.1	339.8	548.6

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Table 4 :	FILL LOADS FOR WIDE TRENCH CONDITIONS IN kN/m												
Depth to	Size	1000 x 650		1150 x 750		1650 x 1000		1950 x 1150		2350 x 1350		2650 x 1500	
Crown	Position	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz	Vert	Horiz
(m)	Bd=	1.70	1.85	1.80	2.00	2.10	2.75	2.20	3.05	2.50	3.50	2.70	3.85
0.60		12.0	16.1	13.2	17.9	16.5	24.1	18.7	28.1	21.5	33.2	23.7	37.2
0.70		14.4	19.1	15.7	21.2	19.5	28.4	22.1	33.0	25.4	39.1	28.0	43.7
0.80		16.8	22.2	18.3	24.5	22.7	32.8	25.6	38.1	29.3	45.0	32.3	50.3
0.90		19.3	25.4	21.0	28.0	25.9	37.2	29.2	43.2	33.4	51.0	36.7	56.9
1.00		21.9	28.6	23.8	31.5	29.2	41.8	32.9	48.4	37.5	57.0	41.2	63.7
1.10		24.7	32.0	26.8	35.2	32.6	46.5	36.7	53.7	41.8	63.2	45.8	70.5
1.20		27.6	35.5	29.8	38.9	36.2	51.2	40.5	59.1	46.1	69.4	50.5	77.4
1.30		30.6	39.1	33.0	42.8	39.8	56.0	44.5	64.6	50.5	75.7	55.3	84.4
1.40		33.7	42.8	36.2	46.7	43.5	61.0	48.6	70.2	55.0	82.2	60.2	91.4
1.50		36.9	46.6	39.6	50.8	47.4	66.0	52.8	75.9	59.7	88.7	65.1	98.6
1.60		40.3	50.5	43.2	55.0	51.4	71.1	57.1	81.6	64.4	95.3	70.2	105.8
1.70		43.9	54.5	46.8	59.3	55.5	76.4	61.5	87.5	69.2	102.0	75.4	113.2
1.80		47.6	58.7	50.6	63.7	59.7	81.7	66.0	93.5	74.2	108.8	80.7	120.6
1.90		51.4	63.0	54.6	68.2	64.0	87.2	70.7	99.5	79.2	115.6	86.1	128.2
2.00		54.7	67.4	58.7	72.9	68.5	92.7	75.5	105.7	84.4	122.6	91.6	135.8
2.20		60.3	76.7	66.8	82.6	77.9	104.2	85.4	118.3	95.1	136.9	102.9	151.3
2.40		65.9	86.6	73.0	92.8	87.8	116.1	95.8	131.4	106.3	151.6	114.7	167.2
2.60		71.5	97.1	79.3	103.7	98.4	128.4	106.8	144.9	118.0	166.6	127.0	183.6
2.80		77.1	106.3	85.5	115.1	108.8	141.3	118.4	158.9	130.2	182.1	139.8	200.3
3.00		82.7	114.1	91.7	127.1	116.8	154.7	130.6	173.4	142.9	198.1	153.1	217.5
3.20		88.3	121.9	98.0	136.2	124.8	168.6	142.8	188.3	156.3	214.5	166.9	235.0
3.40		93.9	129.7	104.2	144.9	132.7	183.1	151.9	203.8	170.2	231.4	181.3	253.1
3.60		99.5	137.5	110.4	153.6	140.7	198.2	161.1	219.8	184.8	248.7	196.3	271.6
3.80		105.2	145.3	116.7	162.3	148.7	213.9	170.3	236.3	197.3	266.6	211.9	290.5
4.00		110.8	153.1	122.9	171.1	156.7	230.2	179.4	253.4	208.0	284.9	228.2	310.0
4.50		124.8	172.5	138.5	192.9	176.6	264.1	202.3	298.7	234.6	333.1	260.1	360.7
5.00		138.8	192.0	154.1	214.7	196.6	294.2	225.2	344.6	261.3	384.9	289.7	414.8
5.50		152.8	211.5	169.6	236.5	216.5	324.2	248.1	380.0	287.9	440.3	319.3	472.3
6.00		166.9	231.0	185.2	258.3	236.4	354.3	271.1	415.4	314.6	493.8	348.9	533.5
6.50		180.9	250.5	200.8	280.1	256.4	384.4	294.0	450.7	341.2	536.0	378.5	598.6
7.00		194.9	269.9	216.4	301.9	276.3	414.5	316.9	486.1	367.9	578.2	408.1	648.9
8.00		223.0	308.9	247.5	345.6	316.2	474.6	362.7	556.8	421.2	662.7	467.3	744.0
9.00		251.0	347.8	278.7	389.2	356.1	534.7	408.5	627.6	474.5	747.1	526.5	839.0
10.00		279.0	386.8	309.9	432.8	396.0	594.9	454.3	698.3	527.7	831.6	585.7	934.1

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Table 5 :	PRESSURE DUE TO VEHICLE LOADING IN kN/m^2	
Depth (m)	**HB 45**	**FIELD**
0.6	119.9	69.5
0.7	103.2	57.5
0.8	90.7	48.6
0.9	81.1	41.6
1.0	73.5	36.1
1.1	67.3	31.6
1.2	62.2	27.8
1.3	57.9	24.7
1.4	54.2	22.0
1.5	51.0	19.8
1.6	48.2	17.8
1.7	46.7	16.1
1.8	45.5	14.7
1.9	44.2	13.4
2.0	42.8	12.3
2.2	40.0	10.4
2.4	37.1	8.9
2.6	34.4	7.7
2.8	31.8	6.7
3.0	29.4	5.9
3.2	27.2	5.2
3.4	25.1	4.7
3.6	23.3	4.2
3.8	21.6	3.8
4.0	20.0	3.4
4.5	16.7	2.7
5.0	14.1	2.2
5.5	12.1	1.9
6.0	10.4	1.6
6.5	9.0	1.3
7.0	7.9	1.2
8.0	6.2	0.9
9.0	5.0	0.7
10.0	4.1	0.6

Table 6 :	WATER LOADS IN kN/m	
Elliptical Vertical	1000 x 650	8.5
	1150 x 750	11.3
	1650 x 1000	21.2
	1950 x 1150	29.0
	2350 x 1350	41.4
	2650 x 1500	51.9
Elliptical Horizontal	1000 x 650	2.0
	1150 x 750	2.7
	1650 x 1000	5.0
	1950 x 1150	6.8
	2350 x 1350	9.7
	2650 x 1500	12.2

4. Bedding Details

The following bedding types are recommended for use with Elliptical pipes in both the vertical and horizontal orientations. The bedding factor f_m is the ratio of the applied load in the installed position to the required minimum works proof test load at works.

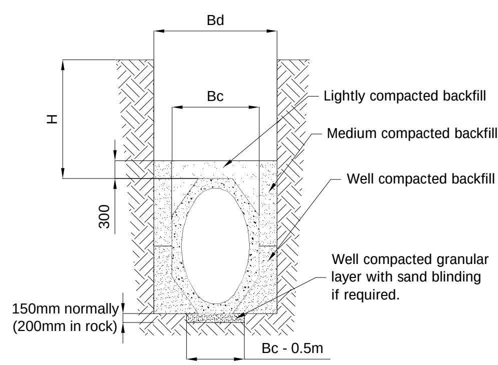

Fig 3: Standard Bedding, f_m = 1.5

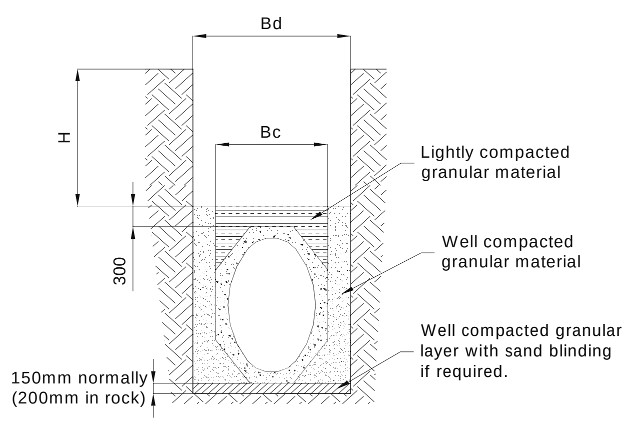

Fig 4: Full Bed and Surround, fm = 1.9

5. Design Procedure

5.1 Summary of Procedure

For the section of pipeline to be designed

a) Establish minimum and maximum cover to crown.

b) Establish type of installation wide or narrow trench.

c) Establish type of vehicle loading.

d) From table 3 or 4 as appropriate read off the fill loads in kN/m for both minimum and maximum cover.

e) From table 5 read off the pressure due to vehicle loading at both minimum and maximum cover.

To obtain the vehicle load on the pipe multiply the pressure by the value of B_c appropriate to the size of pipe.

f) For each depth of cover sum the fill load, vehicle load and water load from table 6 to obtain a total load for the minimum and a total load for the maximum covers.

The greater of the two loads is the total external design load in kN/m.

g) Divide the total external design load by the bedding factor appropriate to the bedding detail selected to give the required works proof load in kN/m.

It is important to state orientation when specifying Elliptical pipe.

Elliptical pipes are available in strength classes of up to 150 kN/m depending on size and orientation.

Designers should check class availability with Stanton Bonna prior to specifying.

5.2 Design Example

A 1650 x 1000 Elliptical pipe is to be laid in a vertical orientation in a trench of width not exceeding 2.10 m at a depth of between 1.1 and 2.6 m to crown.

The pipeline passes under a main road and HB 45 loading is specified.

Fill loads from table 3

at 1.1 m	=	32.6 kN/m
at 2.6 m	=	91.5 kN/m

Vehicle pressure from table 5

at 1.1 m	=	67.3 kN/m^2

at 2.6 m = 34.4 kN/m^2

Vehicle load, (B_c = 1280 mm)

at 1.1 m = 67.3 x 1.28 = 86.1 kN/m
at 2.6 m = 34.4 x 1.28 = 44.0 kN/m

Water load from table 6

Water load = 21.2 kN/m

Total loads

at 1.1 m = 32.6 + 86.1 + 21.2 = 139.9 kN/m
at 2.6 m = 91.5 + 44.0 + 21.2 = 156.7 kN/m

Total external design load

Maximum of total loads at 1.1 and 2.6 m depth

= 156.7 kN/m

Class of pipe required for 'Standard Bedding'

Works proof load required = $\frac{156.7}{1.5}$

= 104.5 kN/m

Specify 1650 x 1000 VERT Proof load = 105 kN/m

Class of pipe required for 'Full Bed and Surround' bedding

Works proof load required = $\frac{156.7}{1.9}$

= 82.5 kN/m

Specify 1650 x 1000 VERT Proof load = 83 kN/m

6. Special Circumstances

6.1 Floatation

Where there is a possibility that the water level in the surrounding ground may be above the water level in the pipeline, the risk of floatation should be assessed.

6.2 Bends and Junctions

Bends and junctions are not normally designed as load bearing structures. Additional measures should be assessed and provided, for example the provision of a properly designed in situ surround.

6.3 Low Cover to Crown

For depths of cover outside the range of the tabulated data, refer to Stanton Bonna.

6.4 High Loading

When calculated loads exceed the strength classes and bedding combinations specified in this document refer to Stanton Bonna.

7. Notes

7.1 The bedding factors used for Elliptical pipe are based on those used for the design of elliptical pipes in ref 2.

7.2 Stanton Bonna Elliptical pipes have an ultimate strength of not less than 1.25 times the proof load strength. If a greater factor of safety is required this should be specified.

7.3 The guidance given in the document assumes that the installation is afforded a reasonable standard of workmanship and supervision on site.

7.4 Pipes should not be crossed by vehicles at depths not allowed for in the design.

7.5 It is recommended that sewers laid in highways should have a minimum cover from crown to road surface of 1.2 m. In other areas a minimum cover of 0.9 m is normally sufficient, see ref 3.

7.6 Removal of trench sheeting or other supports should be undertaken progressively as material is placed and compacted. If removal of trench sheeting is delayed, the narrow trench loads given in table 3 are not valid.

7.7 When pipes are laid in an embankment an enhancement of the bedding factor can be applied under certain circumstances. Further information may be found in ref 1.

7.8 The fill load tables in the document apply to single pipelines laid in 'narrow' or 'wide' trench. For special applications such as multiple pipes in trench or pipelines on piles please contact Stanton Bonna.

7.9 It is essential to ensure uniform support of the pipeline. Hard or soft spots in the formation should be removed and replaced with bedding or selected backfill material. During laying ground water should be kept below the bottom of the trench. In conditions of unstable ground special precautions may be necessary.

7.10 Angular bedding material such as crushed gravel or rock is recommended as bedding for Elliptical pipes. The material should be of similar particle size to that of the ground in which the trench is excavated in order to avoid migration of fines to or from the bedding. Alternatively a geotextile membrane can be used to separate the bedding from the surrounding soil. Where gradients are steep or where there is a possibility of groundwater movement that could risk disturbing the bedding, special precautions should be considered. Maximum particle size should not exceed 40 mm. Under no circumstances should blocks or bricks be placed beneath pipes and any pegs used for setting out or levelling must be removed.

7.11 The bedding material in the bottom of the trench should be laid to the specified thickness and levelled. The material directly under the units should be fully compacted. The surface may be blanded with fine material to assist levelling. In order to prevent collection and trapping of bedding material in the bottom of the joint, a 25 mm deep, 100 mm wide niche shall be dug in front of the joint of the previously laid pipe. The niche should extend either side of the base of the unit. An alternative to a granular bedding is a 75 mm thick lean mix concrete blending that should be laid on a trench bottom of uniform firmness.

7.12 Backfilling should proceed as soon as possible after laying. Material should be placed in layers and compacted, where necessary, evenly on both sides of the pipe. It should be carefully placed in position and not dropped or bulldozed into the trench. Trench supports should be removed as backfilling proceeds, particularly in the case of 'Full Bed and Surround' bedding.

7.13 Material for backfill should be similar in character to the surrounding soil. It should be readily compactable, free from large lumps, roots, rubbish and building rubble. Compaction requirements for backfill material are governed by activities that occur over the pipeline. However, it is important to ensure that no hard spots are created over the pipe which can cause point loading.

7.14 For installation instructions refer to Stanton Bonna Data Sheet PD29 - Installation of Elliptical Pipes.

8. References

1. A guide to design loadings for buried rigid pipes. TRRL HMSO 1983.

2. Concrete Pipe Design Manual. American Concrete Pipe Association 1990.

3. Sewers for Adoption 4th Edition. WRc 1995.

4. BS EN 1295 Structural Design of buried pipelines under various conditions of loading. Part 1. General requirements. BSI 1998.

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