APPENDIX 3.4

CALCULATION OF BACKWATER CURVE

35—51 CPHEEO/ND/94

APPENDIX 3.4

CALCULATION OF BACKWATER CURVE

Problem:

A 3m Diameter Circular sewer laid on a gradient of 0.5/1000 discharges 3 cumecs into a pump well. The Waste water level in the pump well rises to full depth of 3 meters above invert of incoming sewer. Assume a Manning's n value of 0.012 and trace the profile of the back water curve till the flow becomes normal at a depth of 1.2 meters.

Solution:

A 3m diameter sewer on a grade of 5×10^{-4} has a capacity of 10.856 cumecs

$$V = \frac{1}{0.012} x (3/4)^{2/3} (5 x 10^{-4})^{1/2}$$

$$\frac{1}{0.012} x 0.8247$$

V = 1.5367 m/sec.

Q full = 10.856 cumecs.

q/Q = 3/10.856 = 0.276

For q/Q of 0.276 d/D is approximately 0.40 for variable n/N.

Hence initial depth of flow is 0.4 x 3 = 1.2m and the terminal depth = 3m

The length of reach in which the depth changes by a chosen amount is given by Eq.3.16

$$i.e \Delta l = \frac{\Delta(d + hv)}{S_e - S_a}$$

The calculations are made in a Tabular form and presented in the Table.

The length of run in which transition from 1.2m to 3m takes place is about 5355m.

APPENDIX 3.4

CALCULATION OF BACK WATER CURVE.

dm	d/D	a/A	r/R	n/N	a	r	v	hv x 10**2	d+hv	n x10**2	nv x 10**2	AVERAGE R	R**(2/3)	nv x 10**2	S x 10**5	(Se-Sa) x 10**5	(d+hv)	Delta l	Cimulative length
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3.00	1.00	1.000	1.000	1.00	7.07	0.75	0.42	0.90	3.09	1.20	0.504								0
												0.83	0.88	0.59	4.50	45.50	0.68	1495	
2.40	0.80	0.858	1.217	0.89	6.06	0.91	0.50	1.27	2.41	1.35	0.675								1495
												0.87	0.91	0.83	6.32	41.68	0.59	1416	
1.80	0.60	0.626	1.110	0.82	4.42	0.83	0.68	2.36	1.82	1.46	0.990								2911
												0.74	0.82	1.36	27.50	22.50	0.55	2444	
1.20	0.40	0.373	0.857	0.79	2.64	0.64	1.14	6.62	1.27	1.52	1.730								5355

Column 1 = Assumed depth between initial depths of 1.2 mt. and terminal depth of 3.0 mt.

Column 2 = (Column 1) /3

Column 3,4 and 5 = Read from figure

Column 6 = (Column 3) x area of sewer

Column 7 = (Column 1) x hydraulic radius of sewer

Column 8 = rate of flow / (column 6)

Column 9 = (v ** 2) / 2g for column 8

Column 10 = (column 9) + (column 1)

Column 11 = 0.012 (Mannings N) / (column 5)

Column 12 = (Column 11) x (column 8)

Column 13 = Arithmetic mean of successive pairs of values in column 12

Column 14 = (column 13) ** 2/3

Column 15 = Arithemetic mean of successive pairs of values in column 10

Column 16 = = (column 15 / column 14) ** 2 i.e.. S = (nv / (r ** 2/3)) ** 2

Column 17 = (column 16) - i

Column 18 = Difference between successive pairs of values in column 10

Column 19 = (column 18) / (column 17 x 10 ** -5) i.e.. Delta l = Delta (d + hv) / (Se - Sa)

Column 20 = Cumulative values of column 19

APPENDIX 3.5

DESIGN OF SANITARY SEWER SYSTEM

Problem:

Design a system of sanitary sewers for the given area shown in the figure 5 with the following details:

1. Population Density	-	300 persons/hect.
2. Water Supply	-	250 lpd/head (ultimate).
3. Maximum rate of infiltration	-	20,000 lpd/hect.
4. Minimum depth of cover to be provided over the crown of the sewer.	-	1 m.
5. Minimum velocity in sewer at peak flow.	-	0.6 mps
6. Maximum velocity in sewer	-	2.0 mps
7. Minimum size of the sewer	-	150 mm
8. Waste water reaching sewers	-	90% of W/S
9. Peak flow	-	3.5 x Ave flow

Solution:

1. Draw a line to represent the proposed sewer in each street or valley to be served. Near the line indicate by an arrow the direction in which sewage is to flow.

2. Locate the manhole, giving each an identification number.

3. Sketch the limits of the service areas for each lateral.

4. Measure the areas (ha) of the several service areas.

5. Prepare a table as shown in Table 2 with the columns for the different steps in computation and a line for each section of sewer between manholes.

   Column 1-6 for the line manhole, location of the manhole, manhole numbers, ground level at starting manhole and length of line between the manholes.

   Column 7-8 the corresponding area for the next street of sewer and in col.8 the sum of the areas are entered.

Column 9 the population served by each corresponding line is entered.

Column 10 shows the sewage flow (mld) through each line. The sewage flow is assumed as 90% of the per capita water supply.

Column 11 shows the ground water infiltration for each area = 20,000 x 10^{-6} x Col.8.

Column 12 gives the peak flow i.e. Col.10 x 3 + Col.11.

Column 13 gives the peak flow in lps.

Column 14-15 indicate the diameter and slope of the pipes determined from the Manning's chart.

Column 16-17 indicate the discharge through pipe flowing full and the actual discharge through the pipes i.e. as Col.13.

Column 18 also determined from the Manning's Chart when pipe following full.

Column 19 calculated from the hydraulic elements curve for the circular pipes.

Column 20 gives Col.6 x Col.15.

Column 21-22 invert levels of the lines are calculated.

TABLE 2

DESIGN OF A SEWER SYSTEM

Line	Location	Manhole From	Manhole To	Ground level at starting manhole	Length m	Area Served (ha) Increment	Area Served (ha) Total	Population	Sewage flow mld	Ground water infiltration mld	Peak flow mld	Peak flow lps	Diameter mm	Slope	Discharge lps Q Full	Discharge lps Q Actual	Velocity mps V Full	Velocity mps V Actual	Total fall m	Invert Elevation m Upper end	Invert Elevation m Lower end
1	2.	3	4.	5.	6.	7.	8.	9	10.	11.	12.	13	14.	15	16.	17.	18.	19.	20.	21.	22.
1.	Street	R.8.5	R.8.4	38.275	120	0.80	0.80	240	0.054	0.016	0.205	2.37	150	.008	14	2.37	0.75	0.57*	0.96	37.125	36.165
2	Street	R.8.4	R.8.3	37.960	116	1.20	2.00	600	0.135	0.040	0.512	5.92	150	.008	14	5.92	0.75	0.72	0.93	36.135**	35.205
3.	Street	R.8.3	R.8.2	36.873	114	1.40	3.40	1020	0.230	0.068	0.873	10.10	150	.008	14	10.10	0.75	0.82	0.91	35.175	34.265
4.	Street	R.8.2	R.8.1	36.895	116	0.90	4.30	1290	0.290	0.066	1.10	12.73	150	.008	14	12.73	0.75	0.86	0.93	34.235	33.305
5.	Street	R.8.1	8	36.420	75	0.70	5.0	1500	0.34	0.10	1.29	14.92	200	.005	24	14.92	0.70	0.74	0.38	34.275	33.895
6.	Street	8	7	36.117	41	14.5	19.5	5850	1.32	0.39	5.01	57.96	300	.005	70	57.96	1.0	1.13	0.21	33.845	33.635
7.	Street	7	6	35.830	26	4.8	24.3	7300	1.64	0.48	6.22	71.96	350	.005	100	71.96	1.2	1.32	0.13	33.605	33.475
8.	Main.St.	6	5	35.105	88	2.2	26.5	7950	1.80	0.53	6.83	79.02	350	.005	100	79.02	1.2	1.32	0.44	33.445	33.005
9.	-do-	5	4	34.412	86	7.8	34.3	10300	2.31	0.68	8.76	101.35	400	.0033	125	101.35	1.0	1.12	0.29	32.975	32.685
10.	-do-	4	3	34.181	36	5.0	39.3	11800	2.65	0.70	10.05	116.28	400	.0033	125	116.28	1.0	1.14	0.12	32.655	32.535
11.	-do-	3	2	34.105	77	1.2	40.5	12150	2.73	0.80	10.35	119.75	400	.0033	125	119.75	1.0	1.14	0.26	32.505	32.245
12.	-do-	2	1	34.905	117	5.0	45.5	13650	3.07	3.91	11.65	134.79	450	.0033	160	134.79	1.0	1.12	0.39	32.208	31.811
13.	-do-	1	0	33.250	41	1.7	47.2	14200	3.2	0.94	12.14	140.46	450	.0033	160	140.46	1.0	1.12	0.14	31.788	31.641

* Since VEL is less than 0.6 mps, flushing once a day is necessary.

** A minimum level difference of 30mm has been provided between the incoming and outgoing sewers to provide necessary slope in the manhole

APPENDIX 3.6

DESIGN OF GRAVITY SANITARY SEWER NETWORK USING COMPUTER PROGRAMME IN BASIC

The sewer network consists of links (pipes) and nodes (manholes). The pipes are connected by the manholes. One or more links come and join at a node and the sewage is discharged through a downstream link which goes into another manhole. Thus the sewer network consists of links and nodes as if they are connected to a branch of a tree.

The design of sewer network involves selection of appropriate size and slope of a link so as to connect the succeeding node to transport the sewage while meeting the requisite hydraulic parameters. Identification of suitable size of pipe and the corresponding slope form an important part in the sewer network design. An estimate can be made to select each available commercial diameter for a link so that it will meet the constraint of design velocity, quantity of flow, depth of flow, minimum cover depth etc.

A computer (SEWER) programme developed in BASIC language optimises the design of a sewer network for a given layout, flows and pipe diameters by minimising depth of excavation but at the same time meeting the design constraints of excavation depths, scour velocities, maximum velocities etc.

Before collecting the data it is necessary that the requisite drawing showing the ground profile and geomtery of the network has to be prepared. The data needed to design the SEWER network are pipe lengths, diameters, nodal demands, ground levels of the nodes, other design constraints such as peak factor, minimum and maximum allowable velocities, Manning's coefficient, maximum cover depth, outfall nodal demand, ground elevations, number of nodes, links etc.

The programme assumes linear ground profiles between the nodes. If the ground profile has depression or hills, then nodes should be introuduced at these points.

The SEWER programme can determine minimum and maximum allowable slopes based on minimum and maximum allowable velocities provided. The minimum slope for each link has to be increased if the pipe is flowing more than full so that the pipe flows just full. the actual slope with which the pipe is laid is between the maximum and minimum slopes provided. The pipe slope is chosen to minimise the excavation depth and maintain minimum cover depth for all the links. Since the total cost of the sewer network is a function of both the sizes of pipes and their depths and the quantity of excavation, the programme is run several times so that an appropriate pipe network is obtained.

DESIGN OF THE SEWER NETWORK

If all the data of the network entered are correct then the programme can be RUN to design the network. The more complicated and larger the network, it will take more time to design. The process include renumbering of the nodes and links, assignment of flows, determination of maximum and minimum slopes, calculation of actual pipe slopes and their elevations, determination of velocities and depths of flows in the links, checking of the minimum cover depth and reassigning the original link and node numbers.

The result includes the peak flows, water depths, pipe slopes, minimum slopes, maximum slopes and ground slopes for each link. Also the u/s and d/s ground elevations, crown elevations, invert elevations and excavation depth for each link is given. In respect of nodes, the total excavation depth and the difference in elevation of the highest invert entering the node and that of leaving the node is given. The total length of links in the network, the average weighted diameter and excavation depth and excavation area are also given.

The programme compares crown elevation of connected pipes and ignores minor head losses. Thus the final design is only an approximation wihch can be refined by the design engineer. The programme assumes that the network has only one outfall and uses Manning's equation to determine the pipe slopes. It assumes that any pipe flowing at 80% full is flowing completely full.

A typical sewer network diagram, the information and data required as input for the computer, results of the SEWER programmes as run in the computer etc., are given below.

DATA AND INFORMATION REQUIRED AS INPUT TO DESIGN A SEWER NETWORK USING MICROCOMPUTER

The BRANCH programme avaialbe for SEWER design is capable of designing 300 links and 301 nodes.

The information required to be fed into the computer for the Sewer Design is divided into 3 major parts:

i. System information
ii. Link data
iii. Node data

The nodes and links can be numbered between 1 to 36000, all +ve integers. They need not to be consecutive.

The system data includes the following:

i. Project title
ii. Units to be adopted
iii. Number of the outfall node
iv. Peak factor
v. Minimum and Maximum velocities
vi. Manning's coefficient
vii. Maximum cover depth

The link data includes the floowing:

i. Link numbers from' and `to' i.e. the link number of starting node and ending node
ii. Length, diameter of the link
iii. Minimum cover depth for the link

The node data includes the following:

i. Node number

ii. Flow input at the node (flow inputs are entered as +ve and flow outputs are -ve. The only node which will have demand or output is the outfall node). Wherever transitions and other changes are encountered, a junction node can be introduced.

iii. **Ground Elevation**

A model network diagram, the input data, the results of the SEWER.BAS run to design the network is as follows.

SEWER

Version 2.0

Sewer Piping Network
Simulation Program

Limits

LINKS: 300
NODES: 301

September 1986
* * NOT FOR DISTRIBUTION * *

Press any key to start

SEWER File: SAMPLE

T I T L E	:	TEST
NO. OF LINKS	:	12
NO. OF NODES	:	13
PEAK FACTOR	:	2.5
MIN VELOCITY (mps)	:	.61
MAX VELOCITY (mps)	:	2.44
MAX COVER DEPTH (m)	:	4.5

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1 : Total = 12 SEWER File : SAMPLE

LINK NO.	FROM NODE	TO NODE	LENGTH (m)	DIA (mm)	MANNINGS COEF.	MIN COVER DEPTH (m)
1	1	2	60	150	.013	1.5
2	2	3	100	200	.013	1.5
3	4	3	75	150	.013	1.5
4	3	6	75	300	.013	1.5
5	5	6	125	150	.013	1.5
6	6	7	60	600	.013	1.5
7	8	6	45	350	.013	1.5
8	9	8	70	300	.013	1.5
9	13	9	45	200	.013	1.5
10	10	13	45	200	.013	1.5
11	11	9	110	200	.013	1.5
12	12	11	125	150	.013	1.5

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PgUp/Dn - Review
[ESC] - Menu [D] - Delete [C] - Copy [END] - Last Tab - Next Window

1 : Total = 13 SEWER File : SAMPLE

NODE NO.	FIX	FLOW (lps)	ELEV (m)
1		9.55	60
2		6.308	54
3		6.308	53
4		2.523	53
5		4.416	50
6		3.154	49
7			48
8		5.046	48
9		5.677	50
10		7.885	50
11		6.308	51
12		1.892	51
13			50

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SEWER File : SAMPLE

OUTFALL NODE

NODE NO.	CROWN ELEV.
7	45

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SEWER RESULT :

T I T L E	:	TEST
NO. OF LINKS	:	12
NO. OF NODES	:	13
PEAK FACTOR	:	2.5
MIN SCOUR VEL. (mps)	:	.61
MAX VELOCITY (mps)	:	2.44
MAX COVER DEPTH (m)	:	4.5
SEWER OUTFALL NODE	:	7
CROWN ELEVATION OF OUTFALL NODE (m)	:	45
TOT SYSTEM LENGTH (m)	:	935
AVE WEIGHTED DIAM (mm)	:	227.8075
AVE EXC. DEPTH (m)	:	2.056898
AVE EXC. AREA (sq.m)	:	.4926577

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LINK NO.	FROM NODE	TO NODE	PEAK FLOW (lps)	LENGTH (m)	DIA (mm)	WATER DEPTH (mm)	VEL (mps)	PIPE SLOPE %	MIN SLOPE %	MAX SLOPE %	GROUND SLOPE %
1	1	2	23.88	60	150	81.33	2.44	7.50	2.76	7.50	10.00
2	2	3	39.65	100	200	154.74	1.52	1.64	1.64	5.34	1.00
3	4	3	6.31	75	150	85.05	0.61	0.45	0.45	20.72	0.00
4	3	6	61.72	75	300	116.22	2.44	4.04	0.46	4.04	5.33
5	5	6	11.04	125	150	102.46	0.86	0.80	0.59	13.16	0.80
6	6	7	147.67	60	600	425.03	0.69	0.08	0.08	2.39	1.67
7	8	6	67.02	45	350	270.79	0.84	0.24	0,24	3.90	2.22
8	9	8	54.41	70	300	232.10	0.93	0.36	0.36	4.44	2.86
9	13	9	19.71	45	200	154.73	0.76	0.41	0.41	8.93	0.00
10	10	13	19.71	45	200	60.83	2.44	8.93	0.41	8.93	0.00
11	11	9	20.50	110	200	154.74	0.79	0.44	0.44	8.66	0.91
12	12	11	4.73	125	150	67.78	0.61	0.55	0.55	26.36	0.00

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LINK NO.	GROUND ELEV		CROWN ELEV		INVERT ELEV		EXCAVATION DEPTH	
	UPSTRM	DNSTRM	UPSTRM	DNSTRM	UPSTRM	DNSTRM	UPSTRM	DNSTRM
1	60.00	54.00	57.00	52.50	56.85	52.35	3.15	1.65
2	54.00	53.00	52.50	50.86	52.30	50.66	1.70	2.34
3	53.00	53.00	51.50	51.16	51.35	51.01	1.61	1.99
4	53.00	49.00	50.53	47.50	50.23	47.20	2.77	1.80
5	50.00	49.00	48.50	47.50	48.35	47.35	1.65	1.65
6	49.00	48.00	46.39	46.35	45.79	45.75	3.21	2.25
7	48.00	49.00	46.50	46.39	46.15	46.04	1.85	2.96
8	50.00	48.00	48.14	46.50	47.84	46.20	2.16	1.80
9	50.00	50.00	48.32	48.14	48.12	47.94	1.88	2.06
10	50.00	50.00	48.50	48.32	48.30	48.12	1.70	1.88
11	51.00	50.00	48.82	48.33	48.62	48.13	2.38	1.87
12	51.00	51.00	49.50	48.82	49.35	48.67	1.65	2.33

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NODE NO.	INPUT (lps)	GROUND ELEV (m)	EXCAVATION DEPTH (m)	DISTANCE HIGH INVERT TO LOW INVERT (m)
1	9.55	60.00	3.15	0.08
2	6.31	54.00	1.70	0.05
3	6.31	53.00	2.77	0.78
4	2.52	53.00	1.65	0.00
5	4.42	50.00	1.64	0.00
6	3.15	49.00	3.21	1.56
7	-59.07	48.00	2.25	0.00
8	5.03	48.00	1.85	0.05
9	5.68	50.00	2.16	0.30
10	7.89	50.00	1.70	0.00
11	6.31	51.00	2.38	0.05
12	1.89	51.00	1.65	0.00
13	0.00	50.00	1.88	0.00

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LINK NO.	VOLUME OF EXCAVATION (cum)	EXCAVATION COST
1	21.59	0.00
2	40.39	0.00
3	20.47	0.00
4	51.45	0.00
5	30.94	0.00
6	98.30	0.00
7	37.85	0.00
8	41.63	0.00
9	17.76	0.00
10	16.12	0.00
11	46.77	0.00
12	37.36	0.00
	460.64	0.00

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APPENDEX 6.1

THREE EDGE BEARING TEST FOR PIPE STRENGTH

The load which the pipe must withstand without failure is termed three-edge bearing strength. For unreinforced concrete pipes, the point of load at which the pipe cracks and fails is the termination of a three-edge bearing test.

For reinforced concrete pipes, these specifications provide two criteria for passing the three-edge bearing test: first, there is an intermediate load based on the apperance of a crack 0.25 mm wide and 0.3 m long. The final requirement for reinforced pipe is the ultimate three-edge bearing strength at the final failure of the pipe where no further load increase can be supported.

In conducting this test, the pipe is placed horizontally on two parallel wooden rails resting on 15cm x 15cm bearing block or other solid support that extends the length of the pipe. An upper bearing block is placed on the top of the pipe. Next, a rigid I-beam or other structural member is placed on the upper bearing block to apply the load to the block.

THREE EDGE BEARING STRENGTHS OF CONCRETE PIPES ARE GIVEN BELOW

TABLE 1

Dia of pipe mm	Load to produce 0.25mm crack (kg/linear meter)				Ultimate load (kg/linear meter)		
	Concrete				Concrete		
	NP_2 P_1 P_2 & P_3	NP_3	NP_4	NP_1	NP_2 P_1 P_2 & P_3	NP_3	NP_4
1.	2.	3.	4.	5.	6.	7.	8.
80	1040	-	-	-	1560	-	-
100	1040	-	-	1560	1560	-	-
125	-	-	-	-	-	-	-
150	1040	-	-	1560	1560	-	-
200	-	-	-	-	-	-	-
250	1140	-	-	1670	1710	-	-
300	1200	-	-	1790	1800	-	-
350	1260	3040	-	1880	1890	4360	
400	1360	3460	3460	2020	2040	5190	5190
450	1480	3760	-	2220	2220	5640	-
500	1660	4160	4160	-	2490	6240	6240
600	1900	4720	4720	-	2850	7080	7080
700	2100	5320	5120	-	3150	7980	7980
800	2300	6060	6060	-	3430	9090	9090
900	2500	6760	6760	-	3750	10140	10140
1000	2680	7400	7400	-	4020	11100	11100
1100	2780	8200	8200	-	4170	12300	12300
1200	2880	9000	9000	-	4320	13500	13500
1400	2900		10610	-	4470	-	17950
1600	2980		12800	-	4470	-	18300
1800	2980		13800	-	4470	-	20700

APPENDIX 6.2

ILLUSTRATIVE EXAMPLES FOR STRUCTURAL DESIGN OF BURIED CONDUITS

The general assumptions relating to the characteristics of soil and other factors for the examples are given below:

i) saturated density of fill(w) = 2000 kg/m^3

ii) k.u. = k.u' = 0.130, ordinary maximum for clay (thoroughly wet)

iii) r_{sd} for rigid conduit on ordinary bedding=0.7 for positive projection and -0.3 for negative projection

iv) projection ratio = 1

v) concentrated surcharge corresponding to wheel load for Class AA wheel loading=6.25T

vi) Impact factor = 1.5

vii) Factor of Safety for safe supporting strength = 1.1

viii) The design also provides for accidental surcharge of drains and accounts for a water load of 75% as per standard practice, based on the assumption that the sewage flow is 3/4 full.

DETERMINATION OF FILL LOADS OVER PIPES

EXAMPLE I

Problem: Determine the fill load on a 1200mm dia. NP_2 Class concrete pipe installed in a trench of width of 2.3m and depth of 4.00m.

Solution: Pipe thickness 't' = 65mm for D of 1200mm

B_c = D+2t=1200+130=1330mm = 1.33m

B_d = 2.3m

H = 4.00 - 1.33 = 2.67 m

∴ H/B_d = (2.67 / 2.3) = 1.16

B_d is < $2B_c$. Hence trench formula is applicable.

C_d = 0.9965 or 1.00 (from table 6.2) for ordinary maximum for clay.

∴ From equation (6.6)

$W_c = C_d.w.B^2_d = 1.00 \times 2000 \times 2.3^2 = 10{,}580$ kg/m.

EXAMPLE II

Problem: Determine the fill load on a 900mm dia NP_2 Class concrete pipe installed in a trench of width 2.1 m and depth 6.0 m.

Solution: Pipe thickness 't' = 50mm for D of 900mm

B_c = D + 2t = 900 + 100 = 1000mm = 1m.

w = 2000kg/m^2

H = 6.0 - 1.0 = 5.0m

B_d = 2.1m

(H / B_d) = (5.0 / 2.1) = 2.38

$2B_c < B_d < 3B_c$ Hence either the trench or embankment formula can be used,

From Table 6.3

c_d = 1.77188 or say 1.8

From Equation (6.6)

$W_c = C_d\, w.B^2_d = 1.8 \times 2000 \times 2.1^2 = 15{,}876$ kg/m or say 16000 kg/m.

EXAMPLE III

Problem: Determine the fill load on a 1200mm dia NP_2 Class concrete pipe installed as a positive projecting conduit under a fill of 7 m height above the top of pipe. The pipe wall thickness is 65mm and the fill weight 2000 kg/m^3.

Solution: Assume $r_{sd} = 0.7$ and $p = 1.0$

$H = 7$ m

$B_c = 1200 + 130 = 1330$mm $= 1.33$m

$H/B_c = 7/1.33 = 5.26$

$r_{sd} \times p = 0.7 \times 1 = 0.7$

$C_c = 9$ (from figure 6.3)

Using equation (6.2)

$W_c = C_c w \; B^2_c = 9 \times 2000 \times 1.33^2 = 31{,}850$ kg/m.

EXAMPLE IV

Problem: Determine the fill load on a 1200mm dia NP_2 Class pipe installed as a negative projection conduit in a trench the depth of which is such that the top of the pipe is 2 m below the surface of natural ground in which the trench is dug. The height of the fill over the top of the pipe is 10 m.

Solution: Assume the width of the trench as 2 m and fill weight, w = 2000 kg/m^3

Assume $r_{sd} = -0.3$ and $p' = 1.0$

$H = 10$m, $B_d = 2.00$m $H/B_d = 10/2 = 5.00$

For values of $p' = 1.0$ $r_{sd} = -0.3$ and $H/B_d = 5.00$

$C_n = 3.2$ (from figure 6.5)

Using equation (6.3)

$W_c = C_n \, w \, B^2_d = 3.2 \times 2000 \times 2.0^2 = 25{,}600$ kg/m

EXAMPLE V

Problem: Determine the load on 1500mm dia conduit in tunnel condition 15 m deep in a soil of silty sand.

Solution: The maximum width of excavation (B_t) may be assumed as 1950mm; and the cohesion coefficient (C) of the soil as 500 Kg/m^2

$K_u = 0.15$ and $w = 1800$ kg/m^3

$H = 15$ m; $B_t = 1.95$ m

$H/B_t = 15/1.95 = 7.7$