Comparison Study between the Use of Plastic and Concrete Pipes for Redesign and Reconstruction of Sanitary Sewer Network in Baghdad City (Hay Al Karadda –Sections 903-905)

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Received on:26/5/2008
Accepted on:7/5/2009

Abstract

Over the recent years, the emphasis on sewerage has increasingly switched from provision of new services to maintenance of existing service at acceptable levels. As a consequence the need is now to rehabilitate existing systems rather than construct new ones.

The common methods of rehabilitation consist lining of the sewer pipes and that was out of the question since it decreases the diameters of the already under size sewer lines.

So that, hence, it was concluded that the best method for rehabilitating the existing system was by total replacement of the undersize sewer lines. This should be done using sewer pipes with better quality material, such as PVC, GRP or first class concrete pipes.

Modern water and wastewater pipe is either organic or inorganic in composition. Today's organic pipe is made of petroleum-derived plastic, which contains preservatives, antioxidants, and stabilizers to slow down the gradual loss in strength that occurs with organic materials[1].

So that redesigned the existing sewer system in AL-Karadda district within the city of Baghdad by computer with the use of QBasic language. The design consist concrete pipes in once and plastic pipes in other to find the best.

Based on the results, it was concluded that the plastic pipes needed gradient (S_{min}) less than concrete pipes (0.004 m/m for plastic, 0.005m/m for concrete), the max. soil cover for plastic pipes was equal to (3.59 m) while for concrete pipes it was equal to (4.25m).In addition the network redesigned on the min. commercial concrete pipe diameter equal to (200mm) while for plastic pipes equal to (250mm) and that will increasing the capacity of the network.

Keywords: comparison; plastic pipe; concrete pipe; redesign; sanitary sewer network.

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https://doi.org/10.30684/etj.27.11.11
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دراسة مقارنة بين استخدام الانابيب البلاستيكية والانابيب الكونكريتية لاعادة تصميم وانشاء شبكة مياه الصرف الصحي لمدينة بغداد (حي الكرادة – محلات 903-905)

الخلاصة

خلال الفترة الماضية اصبح التركيز على كيفية صيانة الخدمات الصحية القائمة اكثـر من انشاء خدمات جديدة . وكنتيجة لذلك اصبح الاحتياج الان الى اعادة تاهيل او ترميم شـبكات مياه الصرف الصحي الموجودة اصلا اكثر من انشاء شبكات جديدة .

عند استعراض عمليات الترميم وجد ان اغلب الطرق الحديثة تتضمن تبطين الانابيب بمادة اخرى وهذا سيؤدي الى تقليل سعتها وهو عكس المطلوب لذلك فأن افضل طريقة للترميم واعادة تأهيل هذه الانابيب هي بابدالها بانابيب اكبر قطرا وأكثر تحملا وبنوعية افضل لاستيعاب التصريف الداخل والزيادة المحتملة فيه .

ان انابيب الماء وانابيب الصرف الصحي العصرية هي اما عضوية او غير عضوية في تركيبها . والانابيب العضوية التركيب الحالية تصنع من البلاستك المشتق من النفط الخام والذي يحوي على مواد حافظة ومضادات للتاكسد ومواد موازنة والتي تبطئ من الفقدان التدريجي للقوة الذي يحدث في المواد العضوية [1].

لذلك تم اعادة تصميم الشبكة في منطقة الكرادة في بغداد على اساس استخدام الانابيـب الكونكريتية مرة والانابيب البلاستيكية مرة اخرى وعند المقارنة لايجاد الافضل بينهما وجـد ان الانابيب البلاستيكية تحتاج الى ادنى ميل (S_{min}) اقل من الانابيب الكونكريتية للحـصول علـى ادنى سـرعة للتنظيـف (V_{min} =0.6m/s) حيـث وجـد ان S_{min} للانابيـب البلاسـتيكية والكونكريتية هو 0.004m/m و 0.005m/m على التوالي وبالتالي فان الانابيـب البلاسـتيكية تحتاج الى حفريات اقل من الكونكريت حيث كان اعلى عمق ترابي للكونكريت هو 4.25m امـا للبلاستيك فكان 3.59m .

بالاضافة الى ذلك فان الشبكة صممت على اقل قطر تجـاري كـونكريتي (200mm) وبلاستيكي (250mm) وهذه الزيادة في القطر تساعد في زيادة سعة الشبكة وجاهزيتها للزيـادة المحتملة في التصريف الداخل .

Introduction

Various studies have been carried out to assess the respective performances of various pipe systems. A recent study – The Sustainable Municipal Pipe Systems project – carried out by Stein & Partner in 2005, set out to examine the environmental impact of leakage and defects in non-pressure sewer systems and to compare the performance of flexible versus rigid pipe materials. Examples of flexible pipes are PVC, PE and PP. Examples of rigid pipes are concrete and clay. The study found the overall defect rates of flexible pipe systems to be on average, one fifth of the rates of rigid pipe systems. Furthermore, the study found that the environmental impact caused by infiltration or exfiltration for flexible pipes was 15% of that for rigid pipe systems.

Flexible pipe systems excelled, primarily because of their flexibility enabling them to accommodate to shifts in the ground which may cause cracking or even collapse for rigid pipe systems. The study looked at sewer pipe lines in Germany, Sweden and The Netherlands[2].

After investigation and gathering relevant to be information about the sewer system of sections 903 and 905 of AL-Karadda in Baghdad which were used in this study as a result of their deteriorated conditions. It was found:

1- The sanitary network constructed according to the population, economical and commercial circumstances at that time.
2- All the network pipes were constructed with 225mm in diameter.
3- During the survey, it was found that most pipes are corroded and it is believed that this is the cause of failure of some pipes in the network.
4- It was revealed that floodings take place during July and August of each year due to the increase of the water use due to air coolers.

Due to the huge design work which was needed to execute the sewer design for both sections, only part of section 903 was used in the subsequent analysis. The result of this analysis is considered to be applicable to the other areas of sections 903 and 905. The part of the sewer system which was chosen consisted of (71) pipes, (70) manholes and one pumping station (14A) Fig.(1).

The Constraint and Assumption in the Design

The following were assumed:

1- Flow is induced by gravitational forces only, no vacuum pressure pipes will be considered in the design.
2- Steady state uniform flow (i.e., design is according to steady and uniform flow design equations).
3- Flow is subcritical to avoid the formation of hydraulic jumps that result in energy dissipation. The subcritical flow conditions are maintained by keeping Froude's number less than one.
4- Minimum allowable diameter which have been used was (0.2m) for concrete pipes and (0.25m) for plastic pipes.
5- Allowable velocity range: the maximum and minimum limits of velocities were taken equal to (3.0m/s) and (0.6m/s), respectively.
6- Minimum pipe cover: a min. cover of pipe, usually (1m), is required for protection against freezing, thawing and excessive loading.
7- Diameter progression: the diameter of any pipe must be equal to or greater than the targets diameter of the pipe just upstream of it and flowing into it. The gradation in the diameter was 0.025m (0.2m, 0.225m, 0.25m,…..etc) for concrete pipes and for plastic pipes, the gradation in the diameter were (0.25m, 0.315m, 0.4m)[3].
8- Invert progression: the upstream invert elevation of any pipe must be equal to or greater than downstream invert elevation of any pipe flowing into the same manhole.
9- Minor losses due to pipes entry into and exist from manholes, plus friction losses in manholes are considered so little as be negligible for straight flow through.
10- The network is tree shaped, i.e., it contains no losses, with its final

collection point being specified in advance by the designers.

11- For every pipe in the network the direction of flow is fixed in advance and flows are predetermined.

12- The Manning's coefficient is taken to be constant so as to get cleaning velocity higher than (0.6m/s) and as a result less excavation depth can be obtained.

13- Pipes are partially filled with flow to a depth not exceeding (0.85*diameter).

14- If a sewer changes direction in a manhole without changing its size, a drop of (30mm) is to be provided in the manhole.

15- If the sewer changes size, the crowns of the inlet and outlet sewers at manholes are to be the same elevation to prevent back flow.

16- If a sewer changes both direction and size the largest drop from assumptions (14) and (15) above is considered.

17- A large drop manhole will be only if the height between the invert lower elevation of the entering pipe to the manhole and the invert upper elevation of the leaving pipe from the same manhole is the more than (0.6m).
Ramp manhole will be used only, if this height is less than (0.6m) and more than (0.25m).

18- The minimum slop (S_{min}) for any pipe was calculated from the following equation [4]:

S_{min} =1/Dmin (where, D_{min} is in millimeters, can be assumed in the first iteration).

Principles of the Hydraulic Design

This design depends on steady and uniform flow to calculate the slope and diameters.

The following equations may be used:

Pon = Mpd * At ---------------- (1)

Ma[5] = 1 + 14/4+$\sqrt{p}$ -------------- (2)

Qs = Arsf * Mpd * At / (60 *24) -- (3)

Qmax = Qs * Ma ---------------- (4)

Qinf = Mri * At *60 -------------- (5)

Qp = Qinf + Qmax ---------------- (6)

Qf = 1/n * $R^{2/3}$ *$S^{1/2}$ *A *60 ----- (7)

Vf = Qf / A * 60 -------------- (8)

Smax = V^2max * n^2 * $(4/D)^{4/3}$ ----- (9)

Hm = GU- INU ------------ (10)

Where:

Pon : No. of the population in (person).

Mpd[6] : Max. population density in the served area (0.018 person / m^2).

At : Commutative served area in (m^2).

Ma : The ratio of the max. sewage flow to the average flow.

P : The population in thousand =(Pon /1000).

Qs : Average sewage flow in (m^3/min).

Arsf[6] : Average rate of sewage flow per capita (taken 1 m^3/capita).

Qmax[6] : Max. sewage flow in (m^3/min).

Qinf[6] : Inf. flow in (m^3/min).

Mri : Inf. rate (taken 0.1*10^{-7} $m^3/m^2/s$).

Qp : Partial discharge or total discharge in the pipe in (m^3 / min).

Qf : Discharge for full flow in (m^3/min).

R : Hydraulic mean depth in (m) and it is assumed in full discharge (D/4).

A : Cross section area of pipe (m^2).

n : Manning's coefficient (taken 0.013 for concrete pipe and 0.01for plastic pipe

Vf : Full velocity in (m/s).

Smax : Slope of the link (m/m).

D : Commercial diameter of the pipe (m).

Hm : Depth of the manhole in (m).

Gu : Ground upper elevation at the manhole (m).
INU : Invert upper elevation of the manhole (m).

Partial Velocity (Vp)

To calculate partial velocity the variation of hydraulic section of this state in the pipes must be know as illustrated in Fig.(2).

Fig.(3), which was given by Steel and McGhee[6], this is a graph of the variation in ratio of part-full flow to full flow (Qp/Qf) and velocity part-full to velocity full (Vp/Vf) with variation of depth of flow pipe diameter (d/D).

For the purpose of the dealing with the curve in computers, it is expressed by polynomial equation. This is equation was determined by regression analysis.

The equation was found to be[7]

$$Y = (65.312 * x^7) - (241.603 * x^6) + (354.973 * x^5) - (264.397 * x^4) + (106.754 * x^3) - (23.877 * x^2) + (3.646 * x) - 0.0007$$

Where
X : Ratio of part-full flow to full flow (RQ = Qp/Qf).
Y : Ratio of depth of flow to pipe diameter (d/D).
Central angle is given by :

$$\theta = 2.\cos^{-1}(1- 2.y)$$

The ratio of the partial velocity to the full velocity (Vr = Vp/Vf) is given by :

$$Vr = [(\theta-\sin \theta)/\theta]^{2/3}.$$

$$Vp = Vr . Vf$$

Discussion of Results

In order to find whether it is better to use plastic pipes instead of the concrete pipes in rehabilitation of sanitary sewer network pipes, it is necessary to redesign the network.

As a result of this design, table (1), for concrete pipes, it was found that most lateral pipes which consisted of (56) pipes were designed with pipes of (200 mm) in diameters and (15) pipeline with larger than this. Hence, the main pipes were increased in diameter from (200mm) for starting pipe to (500mm) for the last pipe which discharge to the pumping station (14A), Fig.(4).

While for plastic pipes in table (2), it was found that (59) pipelines were designed with (250mm) diameter and (12) pipelines with larger diameter. To assert these results, Fig. (5) was drawn which clearly shows that the increase in diameter begin from pipeline No.7 which needed (315mm) in diameter, other pipelines downstream also needed larger diameter than the existing.

Since the plastic pipes needed gradient less than that for concrete pipes (0.004m/m for plastic and 0.005m/m for concrete), the Max. soil cover for plastic pipes was equal to (3.59m) while for the concrete pipes it was equal to (4.25m) that means the plastic pipes need excavation less than concrete pipes.

In addition, the plastic pipes increased the network capacity by large diameter for pipes.

References

[1] ECCO,"No Pipe Dream: Concrete Serves Water Users Best", Environmental Council of Concrete Organizations, ©2000, (Internet).
[2] Plastic Pipes for a Sustainable Future," Environmental Impact, Plastic Pipe Systems are an Excellent Solution for Distributing Drinking Water and for Sewer

Systems", plasticseurope.Org., 2006, (Internet).

[3] Hepworth Plastic International, LTD, (1980), "P.V.C Pipes for Drains and Gravity Sewers", Hepworth Industrial Division, Pollard Moor Works, Padiham, Burnley, Lancs.

[4] Khudenko, B.M, (1987), "Discussion of Self Cleansing Slope for Partially Full Flow", Jour. Of Civil Engineering, pp. (671 – 673).

[5] ASCE, (1982), "Gravity Sanitary Design and Construction", Manual No. 60, By a Joint Committee of the American Society of Civil Engineering and Water Pollution Control Federation.

[6] Steel, E.W., and Mc GHEE, T.J., (1979), "Water Supply and Sewerage", McGraw-Hill, Fifth Edition.

[7] Omran, H.A., (1986), "Analysis and Design of Storm Sewer Network Using Electrical Computers", M.Sc Thesis, University of Technology, Baghdad.

Table 1: Design of Case Study for Concrete Pipes

LINE NO.	MANHOLE NO.		LENGTH (M)	AREA (M^2)	TOTAL AREA	Max. flow m^3/min			slope of sewer	dim. (mm)	d/D	Qf m^3/min	Vf m/sec.	Vp m/sec	Full in sewer (m)	Cover depth (m)	Sewer invert elev. (m)		Depth of Manhole (m)	REM
	FROM	TO				Inf.	Sew	Total									Upper end	Lower end		
1	H18	H17	74	5000	5000	0.003	0.2658	0.2688	0.005799	200	0.285	1.498	0.795	0.6006	0.429	0.1.248	32.4	31.97	1.2	
2	H17	H16	72	5000	10000	0.006	0.5202	0.5262	0.005	200	0.4404	1.391	0.738	0.697	0.38	1.549	31.97	31.61	1.449	
3	H16	H15	60	2250	12250	0.00735	0.6323	0.63965	0.005	200	0.4834	1.39	0.738	0.727	0.3	1.839	31.58	31.28	1.779	Turned30 mm
4	H15	H14	65	2250	14500	0.0087	0.7433	0.752	0.005	700	0.5168	1.39	0.738	0.727	0.325	2.104	31.78	30.955	2.019	
5	H14/3	H14/2	70	3763	3763	0.002257	0.2014	0.203657	0.00739	200	0.2311	1.692	0.896	0.6014	0.517	1.288	32.78	32.262	1.2	
6	H14/2	H14/1	80	3763	7526	0.00451	0.3953	0.39981	0.005	200	0.3757	1.391	0.738	0.645	0.4	1.438	32.262	31.862	1.488	
7	H14/1	H14	75	3763	11289	0.00677	0.5846	0.59137	0.005	200	0.4669	1.3911	0.738	0.716	0.375	1.573	31.862	31.487	1.436	
8	H14	H13	60	5750	31039	0.0186	1.531	1.5496	0.004644	225	0.6949	1.875	0.786	0.615	0.29	2.444	30.93	30.64	2.329	Ramp Manhole
9	H13/3	H13/2	84	3525	3525	0.00211	0.189	0.19111	0.00779	200	0.2201	1.738	0.822	0.6	0.733	1.533	32.71	31.976	1.2	
10	H13/2	H13/1	94	3525	7050	0.00423	0.3711	0.37533	0.005	200	0.3615	1.391	0.738	0.632	0.47	1.86	31.97	31.506	1.733	
11	H13/1	H13	100	3525	10575	0.00634	0.5489	0.55524	0.005	200	0.4528	1.391	0.738	0.7066	0.5	2.09	31.506	31.006	2.063	
12	H13	H12	26	1300	42914	0.0257	2.074	2.0997	0.0048	250	0.7106	2.472	0.899	0.636	0.124	2.814	30.615	30.49	2.68	Manhole
13	H12/5	H12/4	80	3525	3525	0.002115	0.189	0.191115	0.00779	200	0.2201	1.738	0.822	0.6	0.8239	1.464	32.74	32.116	1.2	
14	H12/4	H12/3	80	3525	7050	0.00423	0.3711	0.37533	0.005	200	0.3615	1.3911	0.738	0.632	0.4	1.764	32.116	31.716	1.664	
15	H12/3/3	H12/3/2	58	2900	2800	0.00174	0.1561	0.15784	0.009799	200	0.1845	1.948	1.0335	0.805	0.566	1.478	33.4	32.831	1.2	
16	H12/3/2	H12/3/1	72	4140	7040	0.00422	0.3706	0.37472	0.005	200	0.3612	1.391	0.738	0.632	0.36	1.878	32.831	32.471	1.878	
17	H12/3/1	H12/3	25	3125	7353	0.00441	0.3665	0.39091	0.005	200	0.3708	1.391	0.738	0.64	0.125	1.283	32.441	32.316	1.906	Turned30 mm
18	H12/3	H12/2	80	3525	17928	0.01075	0.9103	0.92105	0.005	200	0.5765	1.391	0.738	0.684	0.4	1.954	31.716	31.316	1.914	Drop Manhole
19	H12/2	H12/1	30	1300	19228	0.01153	0.87309	0.88462	0.005	200	0.6068	1.391	0.738	0.66	0.15	2.044	31.316	31.166	2.154	
20	H12/1	H12	30	1300	20528	0.0123	1.03556	1.04786	0.005	200	0.6399	1.391	0.738	0.631	0.15	2.134	31.166	31.016	2.244	
21	H12	H10	85	4145	67587	0.04055	3.16	3.20055	0.00307	325	0.6761	3.98	0.8	0.845	0.2615	2.894	30.415	30.153	2.934	Drop Manhole
22	H10/3	H10/2	50	2438	2438	0.00146	0.1317	0.13316	0.0118	200	0.1559	2.137	1.134	0.6	0.58	1.85	32.6	32.01	1.2	
23	H10/2	H10/1	22	1045	3483	0.00208	0.1668	0.18888	0.00819	200	0.2156	1.782	0.946	0.608	0.18	1.85	32.01	31.629	2.05	
24	H10/1	H10	98	6862	10485	0.00627	0.5434	0.54967	0.005	200	0.4505	1.391	0.738	0.704	0.48	2.07	31.629	31.338	2.12	
25	H10	H7	75	4218	62270	0.04936	3.785	3.83436	0.00255	350	0.6901	4.678	0.81	0.84	0.214	3.256	30.126	29.914	3.18	Drop Manhole
26	H7/3	H7/2	50	2375	2375	0.00142	0.1284	0.12982	0.1298	200	0.1498	2.2	1.171	0.806	0.63	1.18	32.98	32.35	1.2	
27	H7/2	H7/1	55	2375	4750	0.00285	0.2528	0.25565	0.006199	200	0.2732	1.549	0.822	0.606	0.341	1.285	32.35	32.009	1.39	
28	H7/1	H7	60	3300	8050	0.00483	0.4219	0.42673	0.005	200	0.3908	1.391	0.738	0.658	0.3	1.451	32.009	31.708	1.521	
29	H7	H6	68	2125	92445	0.05546	4.211	4.26646	0.003257	350	0.7139	4.994	0.965	0.654	0.221	3.425	29.914	29.693	3.445	Drop Manhole
30	H6	H5	70	3500	95945	0.0587	4.356	4.4147	0.003257	350	0.7323	4.99	0.865	0.63	0.225	3.316	29.693	29.465	3.656	
31	H5/2	H5/1	50	2500	2500	0.0015	0.135	0.1365	0.0114	200	0.1603	2.1	1.11	0.6	0.57	1.41	32.4	31.83	1.2	
32	H5/1	H5	80	3400	5900	0.00354	0.3122	0.31574	0.0054	200	0.3189	1.446	0.767	0.615	0.432	1.57	31.83	31.398	1.58	
33	H5	H4	40	2750	104595	0.0627	4.711	4.77	0.00266	375	0.729	5.432	0.819	0.606	0.106	3.459	29.44	28.33	3.709	Drop Manhole

Table 1: Cont..

LINE NO.	MANHOLE NO.		LENGTH (M)	AREA (M^2)	TOTAL AREA	Max. flow m^3/min			slope of sewer	dim. (mm)	$\frac{d}{D}$	Qf m^3/min	Vf m/sec.	Vp m/sec	Full in sewer (m)	Cover depth (m)	Sewer Invert elev. (m)		Depth of Manhole (m)	REM
	FROM	TO				Inf.	Sew	Total									Upper end	Lower end		
34	H4/3	H4	90	3375	3375	0.00202	0.1811	0.18312	0.008199	200	0.21202	1.762	0.945	0.801	0.737	1.508	32.1	31.362	1.2	
35	H4/2	H4/1	80	3000	3000	0.0018	0.1614	0.1632	0.009399	200	0.186	1.9	1.012	0.805	0.7519	1.822	32.12	31.368	1.2	
36	H4/1	H4	78	2438	5438	0.00326	0.2884	0.29166	0.0054	200	0.3048	1.446	0.767	0.8	0.421	1.892	31.368	30.945	1.822	
37	H4	H3	50	4100	117508	0.0705	5.235	5.306	0.0025	400	0.7106	6.247	0.828	0.83	0.125	3.841	28.308	29.143	3.765	
38	H3/1	H3	104	5200	5200	0.00312	0.276	0.27912	0.005798	200	0.2917	1.486	0.798	0.807	0.603	1.629	32.08	31.476	1.2	
39	L1/4	L1/3	55	2750	2750	0.00165	0.1482	0.14985	0.0102	200	0.1765	1.98	1.05	0.601	0.581	1.74	32.03	31.469	1.2	
40	L1/3	L1	55	2750	5500	0.0033	0.2916	0.2949	0.0054	200	0.3067	1.446	0.767	0.602	0.297	2.206	31.469	31.172	1.94	
41	L1/2	L1/1	78	4680	4680	0.00281	0.249	0.25181	0.006199	200	0.2711	1.549	0.822	0.603	0.483	1.463	32.45	31.966	1.2	
42	L1/1	L1	80	4680	9360	0.00561	0.488	0.49361	0.005	200	0.4254	1.391	0.738	0.666	0.4	1.833	31.966	31.566	1.89	
43	L1	H3	85	7725	22545	0.01355	1.1338	1.14735	0.0054	200	0.6706	1.446	0.767	0.628	0.351	2.75	31.1[illegible]	30.7[illegible]	2.428	Ramp Manhole
44	H3	H2	55	2406	147699	0.083	6.432	6.524	0.00275	425	0.7086	7.706	0.905	0.667	0.151	4.069	29.158	29.006	4.14	Drop Manhole
45	H2	H1	60	2406	150105	0.09006	6.526	6.6175	0.00275	425	0.716	7.706	0.905	0.6806	0.165	4.23	29.006	28.8417	4.493	
46	J7	J6	25	4265	4265	0.00255	0.2276	0.23015	0.00689	200	0.25	1.948	0.873	0.612	0.175	1.175	33	32.825	1.2	
47	J5	J4	88	3740	8005	0.0048	0.4196	0.4244	0.005	200	0.3695	1.391	0.763	0.657	0.44	1.4840	32.825	32.385	1.375	
48	J4	J3	90	4050	12055	0.00723	0.6226	0.62983	0.005	200	0.4502	1.391	0.738	0.725	0.45	1.794	32.385	31.935	1.684	
49	J3/4/3	J3/4/2	75	3638	3638	0.00238	0.2106	0.21286	0.007399	200	0.2366	1.692	0.898	0.609	0.554	1.585	32.68	32.325	1.2	
50	J3/4/2	J3/4/1	70	4550	8488	0.00509	0.4441	0.44919	0.005	200	0.4029	1.391	0.738	0.669	0.35	1.964	32.325	31.975	1.705	
51	J3/4/1	J3/4	80	6100	14588	0.00875	0.7476	0.75635	0.005	200	0.5182	1.391	0.738	0.726	0.4	2.404	31.975	31.575	2.164	
52	J3/4	J3/3	68	4600	19188	0.0115	0.9711	0.9826	0.005	200	0.6065	1.391	1.738	0.661	0.34	1.87	31.545	31.205	2.635	Turned30 mm
53	J3/3/3	J3/3/2	70	3588	3588	0.00215	0.1923	0.19445	0.00779	200	0.22219	1.738	0.922	0.603	0.545	2.436	31.94	31.394	1.2	
54	J3/3/2	J3/3/1	70	3588	7176	0.0043	0.3775	0.3818	0.005	200	0.3553	1.391	0.738	0.636	0.35	2.656	31.394	31.044	2.615	
55	J3/3/1	J3/3	80	6000	13176	0.0079	0.6781	0.686	0.005	200	0.4977	1.391	0.738	0.798	0.4	2.936	31.044	30.644	2.856	
56	J3/3	J3/1	78	1981	34345	0.0206	1.6839	1.7045	0.005244	225	0.7263	1.95	0.817	0.603	0.409	3.229	30.619	30.209	3.16	
57	J3/1/2	J3/1/1	77	2983	2985	0.00179	0.1606	0.16239	0.009399	200	0.1901	1.907	1.012	0.604	0.724	1.674	32.75	32.026	1.2	
58	J3/1/1	J3/1/3	75	6000	8985	0.00539	0.4691	0.47449	0.005	200	0.418	1.391	0.738	0.678	0.375	1.848	32.026	31.651	1.873	
59	J3/1/3/2	J3/1/3	45	2000	2000	0.0012	0.1084	0.1096	0.0162	200	0.1212	2.504	1.329	0.601	0.729	1.729	32.54	31.811	1.2	
60	J3/1/3/1	J3/1/3	25	2000	2000	0.0012	0.1084	0.1096	0.0162	200	0.1212	2.504	1.329	0.602	0.405	1.435	32.52	32.115	1.2	
61	J3/1/3	J3/1	8	1000	13985	0.00839	0.716	0.72539	0.005	200	0.5094	1.391	0.736	0.732	0.04	1.868	31.651	31.61	2.248	
62	J3/1	J3	50	2500	50830	0.0304	2.4284	2.4588	0.004036	275	0.7052	2.923	0.82	0.63	0.202	3.62	30.159	29.958	3.77	Ramp Manhole
63	J3	J2	55	3380	85245	0.0397	3.1037	3.1434	0.003733	300	0.734	3.545	0.836	0.607	0.209	3.846	29.933	29.72	3.845	Drop Manhole
64	J2/4	J2/3	85	2000	2000	0.0012	0.1084	0.1096	0.0162	200	0.1212	2.504	1.33	0.602	1.377	2.457	32.5	31.123	1.2	
65	J2/3	J2	100	8750	10750	0.00845	0.557	0.56345	0.005	200	0.4584	1.395	0.736	0.709	0.5	2.707	31.093	30.593	2.64	Turned30 mm
66	J2/2	J2/1	80	5800	5800	0.00348	0.307	0.31048	0.0054	200	0.3158	1.446	0.767	0.612	0.432	1.502	32.53	32.098	1.2	
67	J2/1/1	J2/1	35	4500	4500	0.0027	0.2398	0.2425	0.008589	200	0.2613	1.598	0.848	0.609	0.231	1.3	32.44	32.209	1.2	
68	J2/1	J2	50	2800	13100	0.00786	0.6743	0.68216	0.006	200	0.4986	1.391	0.738	0.736	0.25	1.69	32.098	31.848	1.702	
69	J2	J1	55	3500	93595	0.056	4.2548	4.3108	0.003257	350	0.7202	4.995	0.865	0.846	0.179	3.95	29.674	29.494	4.025	Drop Manhole
70	J1	H1	35		93595	0.056	4.258	4.314	0.003257	350	0.7202	4.99	0.865	0.846	0.114	3.955	29.49	29.38	4.205	
71	H1	P.S	7.5		243700	0.148	10.784	10.93	0.0024	500	0.8	11.098	0.94	1.13	0.018	4.25	28.766	28.748	4.858	

Table 2: Design of Case Study for Plastic Pipes

LINE NO.	MANHOLE NO.		LENGTH (M)	AREA (M^2)	TOTAL AREA	Max. flow m^3/min			slope of sewer	dim. (mm)	d/D	Qf m^3/min	Vf m/sec.	Vp m/sec	Full in sewer (m)	Cover depth (m)	Sewer invert elev. (m)		Depth of Manhole (m)	REM
	FROM	TO				Inf.	Sew	Total									Upper end	Lower end		
1	H18	H17	74	5000	5000	0.003	0.2656	0.2686	0.004	250	0.1985	2.933	0.996	0.61	0.296	1.116	32.35	32.054	1.25	
2	H17	H16	72	5000	10000	0.006	0.5202	0.5262	0.004	250	0.267	2.933	0.996	0.753	0.288	1.344	32.054	31.768	1.366	
3	H16	H15	80	2250	12250	0.00735	0.6323	0.63965	0.004	250	0.316	2.933	0.996	0.798	0.24	1.574	31.736	31.496	1.624	Turned 30mm
4	H15	H14	65	2250	14500	0.0087	0.7433	0.752	0.004	250	0.351	2.933	0.996	0.8404	0.28	1.774	31.496	31.236	1.804	
5	H14/3	H14/2	70	3763	3763	0.002257	0.2014	0.203657	0.00559	250	0.149	3.471	1.178	0.608	0.392	1.162	32.73	32.338	1.25	
6	H14/2	H14/1	80	3763	7526	0.00451	0.3953	0.39981	0.004	250	0.248	2.933	0.996	0.693	0.32	1.23	32.338	32.018	1.412	
7	H14/1	H14	75	3763	11289	0.00677	0.5046	0.59137	0.004	250	0.305	2.933	0.996	0.779	0.3	1.29	32.018	31.718	1.28	
8	H14	H13	60	5250	31039	0.0186	1.531	1.5496	0.004	250	0.512	2.933	0.996	0.987	0.24	2.054	31.236	30.996	2.024	Ramp Manhole
9	H13/3	H13/2	94	3525	3525	0.00211	0.189	0.19111	0.00599	250	0.939	3.59	1.219	0.603	0.564	1.364	32.68	32.096	1.25	
10	H13/2	H13/1	94	3525	7050	0.00423	0.3711	0.37533	0.004	250	0.239	2.933	0.996	0.679	0.376	1.599	32.096	31.72	1.614	
11	H13/1	H13	100	3525	10575	0.00634	0.5469	0.55524	0.004	250	0.824	2.933	0.996	0.765	0.4	1.73	31.72	31.3	1.85	
12	H13	H12	26	1300	42914	0.0257	2.074	2.0997	0.004	250	0.613	2.933	0.996	0.885	0.104	2.208	30.896	30.892	2.3	Ramp Manhole
13	H12/5	H12/4	80	3525	3525	0.002115	0.189	0.191115	0.00599	250	0.139	3.59	1.219	0.603	0.479	1.32	32.69	32.21	1.25	
14	H12/4	H12/3	60	3525	7050	0.00423	0.3711	0.37533	0.004	250	0.239	2.933	0.996	0.679	0.32	1.54	32.21	31.89	1.57	
15	H12/3/3	H12/3/2	58	2900	2900	0.00174	0.1581	0.15784	0.00839	250	0.107	4.25	1.44	0.603	0.487	1.397	33.35	32.86	1.25	
16	H12/3/2	H12/3/1	72	4140	7040	0.00422	0.3705	0.37472	0.004	250	0.239	2.933	0.996	0.679	0.288	1.525	32.86	32.57	1.647	
17	H12/3/1	H12/3	25	3125	7353	0.00441	0.3865	0.39091	0.004	250	0.244	2.933	0.996	0.688	0.1	1.105	32.544	32.44	1.805	Turned 30mm
18	H12/3	H12/2	80	3525	17928	0.01075	0.9103	0.92105	0.004	250	0.396	2.933	0.996	0.894	0.32	1.85	31.89	31.57	1.74	Ramp Manhole
19	H12/2	H12/1	30	1300	19228	0.01163	0.97309	0.98462	0.004	250	0.412	2.933	0.996	0.911	0.12	1.71	31.57	31.45	1.9	
20	H12/1	H12	30	1300	20528	0.0123	1.03556	1.04786	0.004	250	0.427	2.933	0.996	0.927	0.12	1.77	31.46	31.33	1.96	
21	H12	H10	85	4145	67587	0.04055	3.16	3.20055	0.00317	315	0.576	4.84	1.035	0.96	0.269	2.44	30.627	30.552	2.523	Ramp Manhole
22	H10/3	H10/2	50	2438	2438	0.00146	0.1317	0.13316	0.012	250	0.08	5.08	1.725	0.6	0.6	1.66	32.55	31.95	1.25	
23	H10/2	H10/1	22	1045	3483	0.00208	0.1868	0.18888	0.0059	250	0.138	3.59	1.22	0.6	0.132	1.88	31.95	31.818	2.11	
24	H10/1	H10	98	6982	10465	0.00627	0.5434	0.54967	0.004	250	0.293	2.933	0.996	0.76	0.392	1.93	31.81	31.426	2.13	
25	H10	H7	75	4218	82270	0.04936	3.785	3.83436	0.00317	315	0.669	4.84	1.035	0.846	0.236	2.73	30.552	30.317	2.76	Drop Manhole
26	H7/3	H7/2	50	2375	2375	0.00142	0.1284	0.12982	0.0128	250	0.641	5.26	1.782	0.802	0.64	1.2	32.93	32.29	1.25	
27	H7/2	H7/1	55	2375	4750	0.00285	0.2528	0.25565	0.0044	250	0.187	3.07	1.045	0.618	0.242	1.262	32.29	32.048	1.45	
28	H7/1	H7	60	3300	8050	0.00483	0.4219	0.42673	0.004	250	0.256	2.933	0.996	0.706	0.24	1.302	32.048	31.808	1.48	
29	H7	H6	66	2125	92445	0.05546	4.211	4.26646	0.00317	315	0.731	4.84	1.035	0.755	0.216	2.925	30.317	30.11	3.04	Drop Manhole
30	H6	H5	70	3500	95945	0.0567	4.358	4.4147	0.00317	315	0.7455	4.84	1.035	0.727	0.222	2.957	30.11	29.887	3.24	
31	H5/2	H5/1	50	2500	2500	0.0015	0.135	0.1365	0.0112	250	0.084	4.91	1.66	0.6	0.56	1.4	32.35	31.79	1.25	
32	H5/1	H5	80	3400	5900	0.00354	0.3122	0.31574	0.004	250	0.217	2.933	0.996	0.643	0.32	1.48	31.79	31.47	1.62	
33	H5	H4	40	2750	104595	0.0627	4.711	4.77	0.0025	400	0.537	8.122	1.077	1.041	0.099	2.877	29.802	29.733	3.347	Drop Manhole

Table 2: Cont..

LINE NO.	MANHOLE NO.		LENGTH (M)	AREA (M^2)	TOTAL AREA	Max. flow m^3/min			slope of sewer	dim. (mm)	$\frac{d}{D}$	Qf m^3/min	Vf m/sec.	Vp m/sec	Full in sewer (m)	Cover depth (m)	Sewer Invert elev. (m)		Depth of Manhole (m)	REM
	FROM	TO				Inf.	Sew	Total									Upper end	Lower end		
34	H4/3	H4	90	3375	3375	0.00202	0.1811	0.18312	0.00639	250	0.312	3.71	1.259	0.603	0.576	1.346	32.05	31.474	1.25	
35	H4/2	H4/1	80	3000	3000	0.0018	0.1614	0.1632	0.0079	250	0.112	4.149	1.409	0.605	0.639	1.509	32.07	31.43	1.25	
36	H4/1	H4	78	2438	5438	0.00326	0.2884	0.29166	0.004	250	0.208	2.933	0.996	0.627	0.312	1.702	31.43	31.118	1.76	
37	H4	H3	50	4100	117508	0.0705	5.235	5.306	0.0025	400	0.571	8.122	1.077	1.004	0.125	3.157	29.79	29.74	3.277	Drop Manhole
38	H3/1	H3	104	5200	5200	0.00312	0.276	0.27912	0.004	250	0.203	0.933	0.996	0.618	0.416	1.436	32.03	31.614	1.25	
39	L1/4	L1/3	55	2750	2750	0.00165	0.1482	0.14985	0.00919	250	0.098	4.449	1.51	0.601	0.506	1.686	31.98	31.474	1.25	
40	L1/3	L1	55	2750	5500	0.0033	0.2916	0.2949	0.004	250	0.209	2.933	0.996	0.629	0.22	2.095	31.474	31.254	1.936	
41	L1/2	L1/1	78	4680	4680	0.00281	0.249	0.25181	0.0044	250	0.185	3.076	1.045	0.615	0.343	1.323	32.4	32.056	1.25	
42	L1/1	L1	80	4680	9360	0.00561	0.488	0.49361	0.004	250	0.276	2.933	0.996	0.738	0.32	1.613	32.056	31.736	1.573	
43	L1	H3	65	7725	22585	0.01355	1.1338	1.14735	0.004	250	0.448	2.933	0.996	0.948	0.26	2.056	31.[illegible]4	30.[illegible]64	2.345	Ramp Manhole
44	H3	H2	55	2406	147699	0.083	6.432	6.524	0.0025	400	0.677	8.122	1.077	0.869	0.137	3.427	29.742	29.673	3.557	Drop Manhole
45	H2	H1	60	2406	150105	0.09006	6.526	6.6175	0.0025	400	0.688	8.122	1.077	0.856	0.15	3.77	29.672	29.523	3.827	
46	J7	J5	25	4265	4265	0.00255	0.2276	0.23015	0.0048	250	0.17	3.213	1.09	0.61	0.12	1.12	32.95	32.83	1.25	
47	J5	J4	88	3740	8005	0.0048	0.4196	0.4244	0.004	250	0.255	2.933	0.996	0.7055	0.352	1.342	32.83	32.47	1.369	
48	J4	J3	90	4050	12055	0.00723	0.6226	0.62983	0.004	250	0.315	2.933	0.869	0.795	0.36	1.562	32.478	32.118	1.59	
49	J3/4/3	J3/4/2	75	3938	3938	0.00236	0.2106	0.21296	0.0052	250	0.158	3.345	1.136	0.606	0.39	1.42	32.83	32.04	1.25	
50	J3/4/2	J3/4/1	70	4550	8488	0.00509	0.4441	0.44919	0.004	250	0.263	2.933	0.996	0.718	0.28	1.73	32.44	32.16	1.669	
51	J/3/4/1	J3/4	80	6100	14588	0.00875	0.7476	0.75635	0.004	250	0.352	2.933	0.996	0.841	0.32	2.09	32.16	31.84	1.979	
52	J3/4	J3/3	68	4600	19188	0.0115	0.9711	0.9826	0.004	250	0.412	2.933	0.996	0.91	0.272	1.492	31.81	31.538		
53	J3/3/3	J3/3/2	70	3588	3588	0.00215	0.1923	0.19445	0.00599	250	0.142	3.59	1.22	0.608	0.419	2.309	31.89	31.47		Turned 30 mm
54	J3/3/2	J3/3/1	70	3588	7176	0.0043	0.3775	0.3818	0.004	250	0.241	2.933	0.996	0.683	0.28	2.46	31.47	31.19		
55	J3/3/1	J3/3	80	6000	13176	0.0079	0.6781	0.686	0.004	250	0.332	2.933	0.998	0.816	0.32	2.66	31.19	30.87	[illegible]	
56	J3/3	J3/1	78	1981	34345	0.0206	1.6839	1.7045	0.004	250	0.534	2.933	0.996	0.965	0.312	2.872	30.87	30.558	2.911	
57	J3/1/2	J3/1/1	77	2983	2985	0.00179	0.1606	0.16239	0.0079	250	0.111	4.148	1.408	0.604	0.616	1.566	32.7	32.084	1.26	
58	J3/1/1	J3/1/3	75	6000	8985	0.00539	0.4691	0.47449	0.004	250	0.2703	2.933	0.996	0.729	0.3	1.666	32.084	31.784	1.816	
59	J3/1/3/2	J3/1/3	45	2000	2000	0.0012	0.1084	0.1096	0.02	250	0.054	6.559	2.23	0.601	0.899	1.9	32.49	31.59	1.25	
60	J3/1/3/1	J3/1/3	25	2000	2000	0.0012	0.1084	0.1096	0.02	250	0.054	6.559	2.23	0.602	0.499	1.529	32.47	31.97	1.25	
61	J3/1/3	J3/1	8	1000	13985	0.00839	0.718	0.72639	0.004	250	0.343	2.933	0.996	0.831	0.032	1.678	31.5[illegible]	31.[illegible]	2.116	
62	J3/1	J3	50	2500	50830	0.0304	2.4284	2.4588	0.004	250	0.703	2.933	0.996	0.768	0.2	3.192	30.558	30.358	3.372	Drop Manhole
63	J3	J2	56	3360	66245	0.0397	3.1037	3.1434	0.00317	315	0.569	4.84	1.035	0.968	0.177	3.351	30.293	30.134	3.487	
64	J2/4	J2/3	86	2000	2000	0.0012	0.1084	0.1096	0.02	250	0.054	6.559	2.23	0.601	1.7	2.77	32.45	30.75		
65	J2/3	J2	100	8750	10750	0.00645	0.557	0.56345	0.004	250	0.296	2.933	0.996	0.768	0.4	2.93	30.72	30.32		Turned 30 mm
66	J2/2	J2/1	60	5800	5800	0.00348	0.307	0.31048	0.004	250	0.215	2.933	0.966	0.64	0.32	1.39	32.48	32.16		
67	J2/1/1	J2/1	35	4500	4500	0.0027	0.2398	0.2425	0.004	250	0.181	3.077	1.045	0.606	0.154	1.22	32.39	32.236		
68	J2/1	J2	50	2800	13100	0.00786	0.6743	0.68216	0.004	250	0.331	2.933	0.996	0.815	0.2	1.53	32.16	31.96	1.639	
69	J2	J1	55	3500	93595	0.056	4.2548	4.3108	0.00317	315	0.737	4.84	1.035	0.746	0.174	3.406	30.134	29.979	3.556	Drop Manhole
70	J1	H1	35		93595	0.056	4.258	4.314	0.00317	315	0.737	4.84	1.035	0.746	0.111	3.517	29.979	29.867	3.72	
71	H1	P.S	7.5		243700	0.146	10.784	10.93	0.002	500	0.8	11.098	0.94	1.13	0.015	3.592	29.4227	29.4077	4.277	

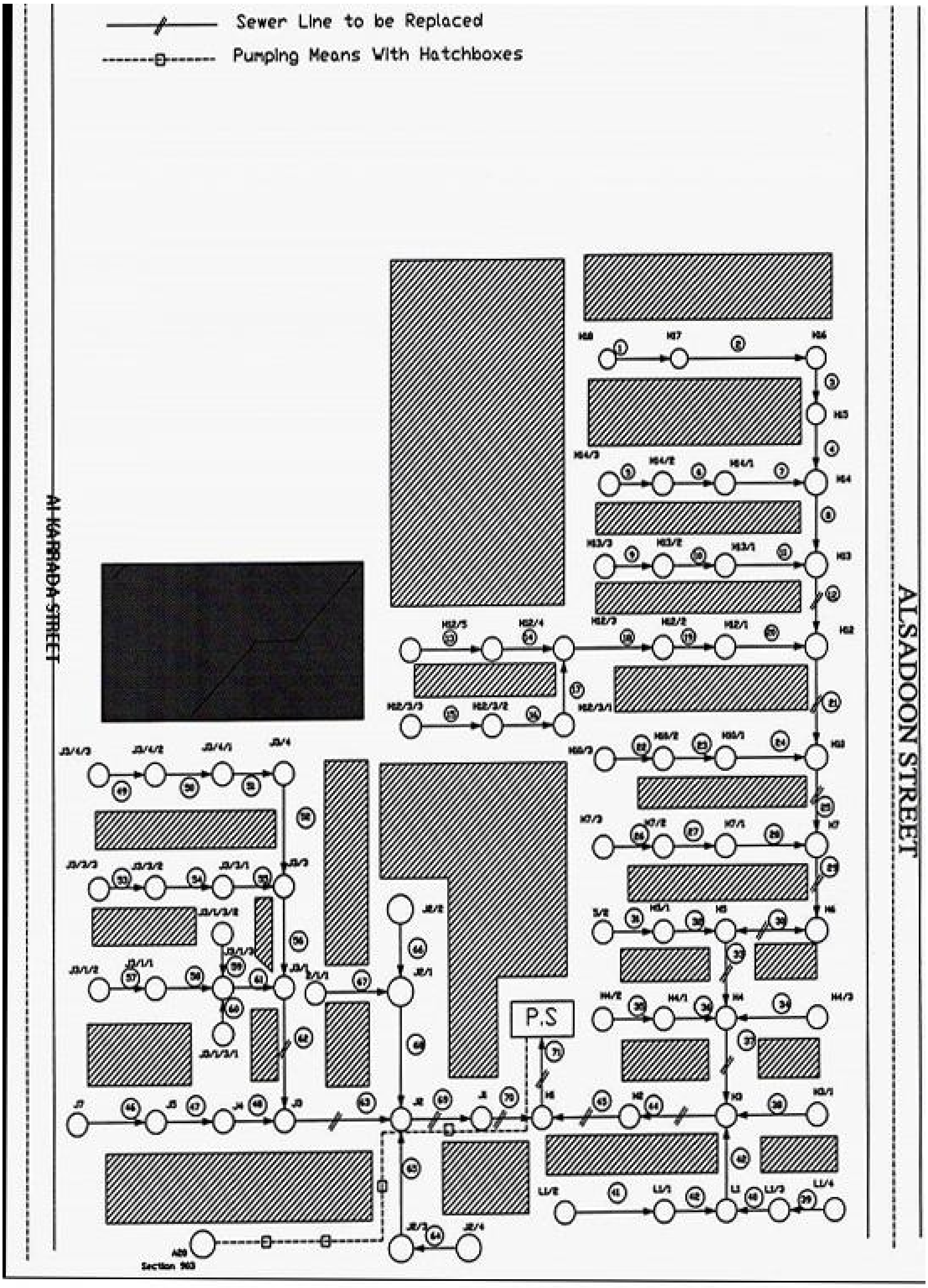

Figure (1) Case study (Karadda city)

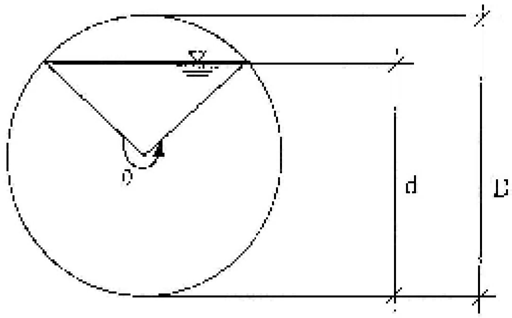

Figure (2) Percentage of sanitary sewers lengths vs. area

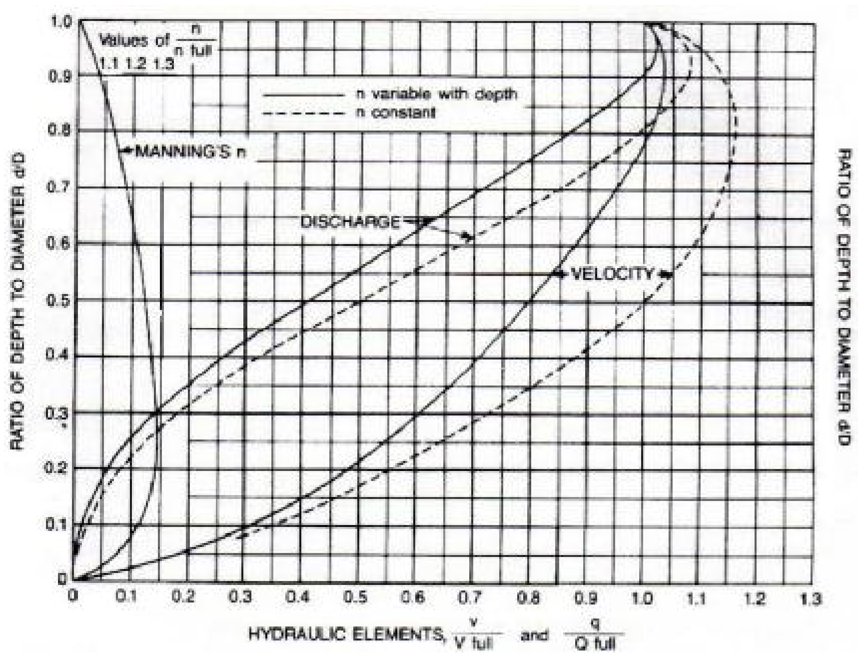

Figure (3) Hydraulic properties of circular sewers

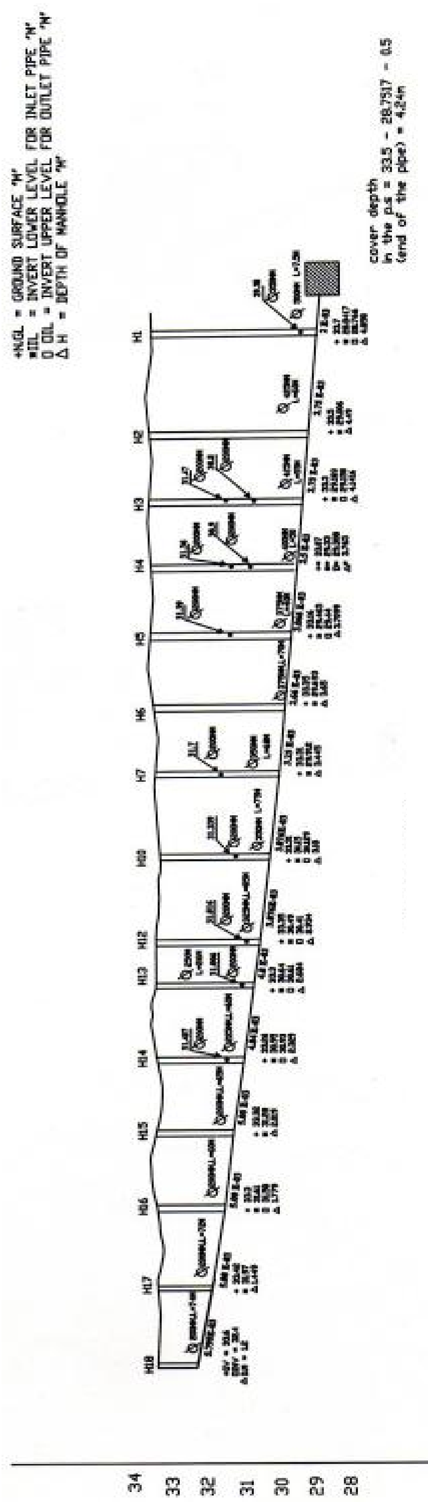

Fig. 4: Profile of the Case Study for Concrete Pipes

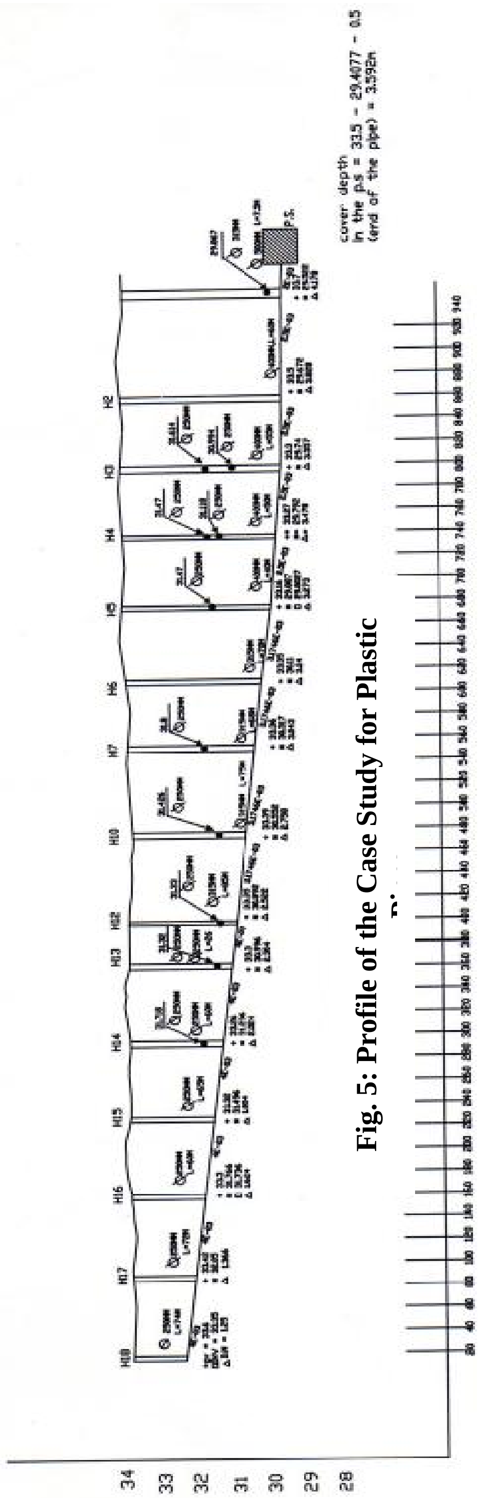

Fig. 5: Profile of the Case Study for Plastic [illegible]