Minimum Velocities and Slopes to be adopted in design of sewer network.

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1.0 INTRODUCTION

1.1 The Government of Gujarat has undertaken a massive programme of providing sanitation facilities to all the towns and large villages of the state.

1.2 Work of preparation of number of sewerage projects is on hand at present. We came across several sewerage projects in which it was observed that there was ample scope of reducing depth of excavation and number of pumping stations. It was found that the main reason for this was maintaining of minimum velocity of 0.3 m/s from the beginning of the sewer section. This will not only result in higher cost of the projects but unaffordable O & M cost also.

1.3 CPHEEO manual specifies that it is necessary to size the sewer to have adequate carrying capacity for the peak flow to be achieved at the end of design period, and also to avoid steeper gradients and deeper excavations. Problem of silting may have to be faced in the early years and for sewers of upper reaches of laterals. In such situations flushing arrangements either fixed or mobile have to be provided.

1.4 The concept of providing minimum size of 200 mm diameter pipe instead of 150 mm diameter pipe as specified in CPHEEO manual will be counteractive to efficient performance and also lead to higher cost of projects. Actually the condition of turbulence for the same velocities, is higher in smaller pipes than in larger pipes. This keeps small pipes cleaner at lower velocities than are required for those of larger size.

1.5 As the Government has taken up so massive programme the fund required will also be very huge. Hence it is absolutely necessary that not only the projects are technically sound and of affordable O & M cost but should be cost effective also.

2.0 In preparation of any sewerage project design of sewer network is a very important part, which ultimately affects the quality and cost of the project substantially. At the same time the recurring O & M cost of the project also depends upon sound design and should be within the affordability of the local body. Otherwise the completed project will not be properly maintained and remain there as only monument. Values of minimum velocities and slopes considered in design of network play very crucial role.

3.0 Sewers are designed on open channel flow basis and Manning formula is widely used for sewer design owing to its simplicity of form and satisfactory results it yields in practice.

3.1 Definitions of some of the terms used for flow in open channel are given below:
Steady Flow and Unsteady Flow: Flow in a channel is said to be steady if the flow characteristics at any point do not change with time. If any of the characteristics changes with time, the flow is unsteady.

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Uniform and non-uniform flow:

Flow is said to be uniform if the depth, slope, cross-section and velocity remain constant over a given length of channel. Flow is said to be non-uniform or varied if the depth of flow changes from section to section along the length of the channel.

Laminar Flow:

In laminar flow the fluid particles move in straight parallel paths in layers, such that the path of the individual fluid particle does not cross those of neighbouring particles. It occurs at low velocity so that forces due to viscosity predominates over inertia forces. The viscosity of fluid induces relative motion within the fluid as the fluid layer slide over each other, which in turn gives rise to shear

Turbulent Flow:

In turbulent flow the fluid particles are in an extreme state of disorder and their movement is haphazard, which results in a thorough mixing of the fluid. Such irregular motion of fluid particles in turbulent flow is on account of the fact that at any fixed point, the velocity and the pressure do not remain constant with time, but fluctuates in irregular manner. In other words, in turbulent flow there are irregular velocity and pressure fluctuations of high frequency superimposed on the main flow. Where velocities are high, fluid particles follow more chaotic paths.

4.0 A sewer has to carry the peak flow for which it is designed and transport suspended solids in such a manner that their deposits in a sewer are the minimum. Sewer design presumes flow to be steady and uniform. Estimated design flows depend to a large extent on certain assumptions, the accuracy of which is variable.

5.0 It is necessary to size the sewer to have adequate carrying capacity for the peak flow to be achieved at the end of design period, and also to avoid steeper gradients and deeper excavations. It is desirable to design sewers for higher velocities wherever possible. This is done on the assumption that although silting might occur at minimum flow, the silt would be flushed out during the peak flows. However problem of silting may have to be faced in the early years particularly for smaller sewers, which are designed to flow partly full at the end of design period, where the depth of flow during early years is only a small fraction of full depth. Similarly upper reaches of laterals pose a problem as they flow only fractionally full even at the ultimate design flow, because of the compulsion of adopting the minimum size of pipe. In such situations flushing arrangements either fixed or mobile may be provided.

6.0 **Peak flow:** The wastewater flow varies through out the day reaching a peak in the morning hours and falls to almost nil during the midnight hours. The peak flow in any sewer can be taken as the average flow in that section multiplied by a peak factor. Peak factors tend to increase as the population contributing to the flow decreases. In upper reaches population will be quite low and hence peak factor will be high than what is assumed in design. Higher peak factors might occur in areas where the water supply is intermittent and households have made limited provision for water storage.

7.0 In the design of sewer an attempt should be made to obtain adequate scouring velocities at the average or at least at the peak flow at the beginning of the design period. It has been shown that for sewers running partially full, for a given flow and slope velocity is little influenced by pipe diameter. Values for n=0.011 is tabulated in table A. It is therefore recommended that for present peak flows upto 30 lps the slopes given in table B may be adopted which ensure a minimum velocity of 0.60 mps in early years.

TABLE A

DIA MM	GRAND IENT 1/L	DISCHARGE IN LPS		VELOCITY AT	
		RUNNING FULL	ACTUAL	FULL FLOW	ACTUAL FLOW
100	165	4.75	**2**	0.61	0.58
150	165	14.02	2	0.79	0.57
200	165	30.19	2	0.96	0.54
250	165	54.74	2	1.11	0.53
300	165	89.02	2	1.26	0.50
350	165	134.28	2	1.39	0.52
400	165	191.71	2	1.52	0.49
150	250	11.39	**3**	0.64	0.54
200	250	24.53	3	0.78	0.53
250	250	44.47	3	0.91	0.51
300	250	72.32	3	1.02	0.51
350	250	109.09	3	1.13	0.48
400	250	155.75	3	1.24	0.94
150	320	10.07	5	0.57	0.57
200	320	21.68	5	0.69	0.56
250	320	39.31	5	0.80	0.55
300	320	63.92	5	0.90	0.54
350	320	96.42	5	1.00	0.58
400	320	137.66	5	1.09	0.52
100	165	4.75	2	0.61	0.58
150	165	14.02	2	0.79	0.57
200	165	30.19	2	0.96	0.54
250	165	54.74	2	1.11	0.53

TABLE B

Present peak flow in lps	Slope per 1000	Slope 1 in L
2	6	165
3	4	250
5	3.1	322
10	2	500
15	1.3	770
20	1.2	833
30	1	1000

7.1 After arriving at slopes for present peak flows, the pipe size should be decided on the basis of ultimate design peak flow and the permissible depth of flow. All sewers are to be designed to flow 0.8 full at ultimate flow. Minimum diameter for a public sewer may be 150 mm. However, the minimum size in hilly areas where slopes are prevalent can even be 100 mm.

7.2 From consideration of ventilation sewers should not be designed to run more than 0.8 full.

7.3 Where it is not possible to obtain self cleansing velocities due to flat gradient especially at the upper ends of branch sewers which receive very little flow, it is essential that some form of flushing device be incorporated in the system. Flushing can be very conveniently accomplished by use of fire hydrant or tanker and hose.

8.0 Even if the pipe invert has a regular fall, solid particles will settle and remain settled unless the fall is such that it gives a velocity of flow sufficient to wash them away. The movement of the larger particles is partly due to the lateral push of water against them, but in sewers the velocities should be sufficient to cause turbulent flow, in which conditions there are eddies which tend to lift all (except very heavy) particles into suspension, otherwise heavy grit will settle and remain settled. A higher flow is needed to transport given concentration of sediment in large sewers than in small sewers.

8.1 Generally, it can be recommended to designers that a velocity of 0.75 m per second will give satisfactory results and freedom from trouble if the sewerage system is otherwise correctly designed and constructed. It must, however, be borne in mind that in order for the sewers to flow at this velocity they must not only flow at 0.75 m per second when full or half-full (the velocity of a circular pipe when running half-full is the same as that of a pipe when running full), but they must flow half-full or nearly half-full at least once during the day. Very seldom is there any difficulty in adhering to the above rule, but if the circumstances should arise in which marked economy would result from adopting a reduced velocity, it would be permissible to work to a velocity of 0.60 m per second for the smaller sizes of pipe (100, 150, 200 and 250 mm diameter), provided the sewers concerned receive adequate flow. This means that in the majority of properly designed sewers a velocity of 0.6 m per second is realised once a day during the time of peak flow.

8.2 Tables 3 and 4, based on Crimp and Bruges' formula, give the gradients and discharges of various sizes of pipe flowing at about 0.75 m and 0.6 m per second

TABLE 3

Minimum Gradient for Best Working Condition in Circular Sewer (Velocity = 0.57 m/s to 0.76 m/s)

		n = 0.013		n = 0.011	
Diameter	Gradient	Discharge Q	Velocity V	Discharge Q	VelocityV
mm	1/l	l/s	m/s	l/s	m/s
100	100	5.17	0.66	6.11	0.78
150	150	12.44	0.70	14.70	0.83
200	200	23.20	0.74	27.42	0.87
250	300	34.35	0.70	40.60	0.83
300	400	48.38	0.68	57.17	0.81
350	520	64.00	0.66	75.64	0.79
400	660	81.11	0.65	95.86	0.76
450	820	99.62	0.63	117.73	0.74
500	970	121.31	0.62	143.36	0.73
550	1100	146.88	0.62	173.59	0.73
600	1300	170.40	0.60	201.38	0.71
650	1400	203.27	0.61	240.22	0.72
700	1500	239.28	0.62	282.79	0.73
750	1650	274.23	0.62	324.09	0.73
800	1700	320.91	0.64	379.25	0.75
850	1850	361.60	0.64	427.35	0.75
900	1900	415.56	0.65	491.12	0.77
950	2050	462.12	0.65	546.14	0.77
1000	2250	505.76	0.64	597.71	0.76

TABLE 4

Absolute Minimum Gradient for Best Working Condition in Circular Sewer (Velocity = 0.6 m/s)

		n = 0.013		n = 0.011	
Diameter	Gradient	Discharge	Velocity V	Discharge	VelocityV
mm	1/L	l/s	m/s	l/s	m/s
100	140	4.37	0.56	5.16	0.66
150	240	9.84	0.56	11.62	0.66
200	300	18.95	0.60	22.39	0.71
250	400	29.75	0.61	35.16	0.72
300	600	39.50	0.56	46.68	0.66
350	700	55.16	0.57	65.19	0.68
400	800	73.67	0.59	87.07	0.69
450	900	95.09	0.60	112.38	0.71
500	1200	109.07	0.56	128.90	0.66
550	1300	135.11	0.57	159.68	0.67
600	1500	158.63	0.56	187.47	0.66
650	1700	184.46	0.56	218.00	0.66
700	1800	218.43	0.57	258.15	0.67
750	2050	246.03	0.56	290.76	0.66
800	2350	272.94	0.54	322.57	0.64
850	2450	314.22	0.55	371.35	0.65
900	2600	355.24	0.56	419.83	0.66
950	2750	398.99	0.56	471.53	0.66
000	2900	445.49	0.57	526.48	0.67

8.3 Some textbooks recommend a range of velocities varying from 0.9 m per second for the smaller pipes and 0.6 m per second for the larger culverts or barrels. The variation of velocity according to the size of sewer was based on a belief that there was greater “transporting power “ in deep water. This belief was fallacious, for it has been shown by experiment that the condition of turbulence which, for the same velocities, is higher in small pipes than in larger pipes. This keeps small pipes cleaner at lower velocities than are required for those of larger size.

8.4 The Building Research Establishment (BRE) has carried out some research into the effects of very flat gradients in house drainage. Pilot experiments have shown that within about 12 m of WC flush, the hydraulics of a drain are dominated by the flush wave, and the gradient of the drain does not seriously influence the frequency of blockage. BRE has reported one such 100 mm diameter drain laid at 1 in 1200 with no history of blockages.

8.5 Conventional sewer calculations assume steady-state conditions. In practice, the flow in sewers at the upper end of the system is highly transient. The amount of flow at any time depends on the number of taps running and WCs being flushed. The largest flows occur when a WC is flushed. The current practice in Brazil is to assume a minimum flow of 1.5 litres per second for the wave created by a flushed toilet.

9.0 Number of sewerage projects are completed by municipal corporations and GWSSB and are functioning without much trouble even though the slopes adopted for upper reach are quite flat. In my opinion some factors as mentioned below may be responsible for this.

9.1 If there are any obstruction heading-up of sewage in manhole takes place. Heading-up will develop sufficient head to flush the sewer. Due to silting of sewer in some section a stage will reach where cross section area is reduced. At some stage velocity through that particular section may increase due to reduction in cross section area, which may flush that section.

10.0 CONCLUSION:

1. Higher peak factors might occur in areas where the water supply is intermittent and households have made limited provision for water storage.
2. For sewers running partially full, for a given flow and slope velocity is little influenced by pipe diameter.
3. The velocity of a circular pipe when running half-full is the same as that of a pipe when running full),
4. The condition of turbulence which, for the same velocities, is higher in smaller pipes than in larger pipes. This keeps smaller pipes cleaner at lower velocities than are required for those of larger size.
5. In sewers the velocities should be sufficient to cause turbulent flow, in which conditions there are eddies which tend to lift all (except very heavy) particles into suspension, otherwise heavy grit will settle and remain settled.
6. Thus there are number of factors which affect actual velocity of flow in field. Hence to adhere strictly to recommendation of CPHEEO manual for maintaining minimum velocity of 0.6 & 0.8 m/s for present and ultimate peak flow respectively should be compromised wherever there is hard soil and or high water table. In such situations sewers can be designed with flatter slopes and if needed sewers should be occasionally flushed. In short a practical approach be adopted that will make the project economical in capital cost and affordable and sustainable in O & M cost that is bound to continuously rise due to increase in cost of components of manpower and energy. If these factors are not taken into account at the project preparation stage, project may result becoming defunct defeating the basic objective of the mission..

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