Economical Design of Sewer Line in Flat Terrain: A Case Study of Rajapur Sewerage System

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Abstract

Design of sewer line in flat terrain is a great challenge due to high excavation depth involved in laying a sewer line required for maintaining minimum velocity, slope and clear cover. Sewer design presented in this paper is result of sewer modelling software Bentley SewerCAD V8i. Estimation and cost analysis of a sewer system shows cost is directly related to the excavation depth. For economically efficient design of sewer line in a flat terrain of Rajapur-Bardia, sewer is designed in the gentle slope and flushing tanks are provided at sections where velocities are less than the minimum value recommended by Codes. Design and cost estimation of sewer network of 4.554 km with and without use of flushing tank are presented in this paper and two major benefits - cost and low invert level of outfall from ground surface elevation are achieved with flushing tank provision.

Keywords: *Sewer line, Flushing tank, economic design*

I. Introduction

Sewer is a basic infrastructure in any society. Nepal is facing rapid urbanization with many infrastructures planned to be constructed. In recent years, water, sanitation and hygiene sector in Nepal is receiving great attention as Nepal is now one of the few countries in the world where citizens' access to safe water and sanitation services and the right to live in a healthy and clean environment have been explicitly mentioned as the fundamental human rights in the new Constitution.

Rajapur municipality is an expanding municipality. Core area of the city has already faced saturated density with appreciable waste water being generated. The situation of sanitation in the selected wards of Rajapur is hopeless as there is direct discharge of sewage into natural drain or in some cases there are poorly designed septic tanks. This has serious impacts on environment and health. The rapidly growing population on the study site is a major challenge in the near future. It is thus important to address the worst practice of sanitation happening in the study site and proper means of treatment and disposal to be devised.

However, owing to the large cost in laying a sewerage network it is therefore important to design sewer in a most possible gentle slope i.e., mimicking natural ground slope and offsetting problem of maintain velocity by provision of flushing tank.

II. General description of the study area

Rajapur is a municipality in Bardiya District in the Bheri Zone of South-Western state 5 of Nepal. It is situated at 28° 26′ 0″ North latitude 81° 5′ 0″ East longitude and 130 meters elevation above the mean sea level. Rajapur is small municipal in Nepal, having about 14000 inhabitants. The Karnali River flows from North-East to South-East direction. Landscape of the project area is flat. Most of the project area includes settlement area and agriculture land. Soil in the project area is moderately fertile. In this municipality, population has been increasing in a high rate (Geometric growth rate of +2.1% from year 2001-2011) [1], [2]. However, poor management and haphazard disposal of sewage on natural drain is degrading beauty of city with alarming threat on health to locality residents.

III. Sewer Network Layout

The network of sewer line in the project area is so selected that the total distance of the trunk line from the farthest point to the outfall point is least possible to reduce excavation depth. Based on this condition, the network is designed with five trunk lines with several laterals draining into it. Another factor considered in network design is avoidance of bends to minimize obstruction of flow during lean season.

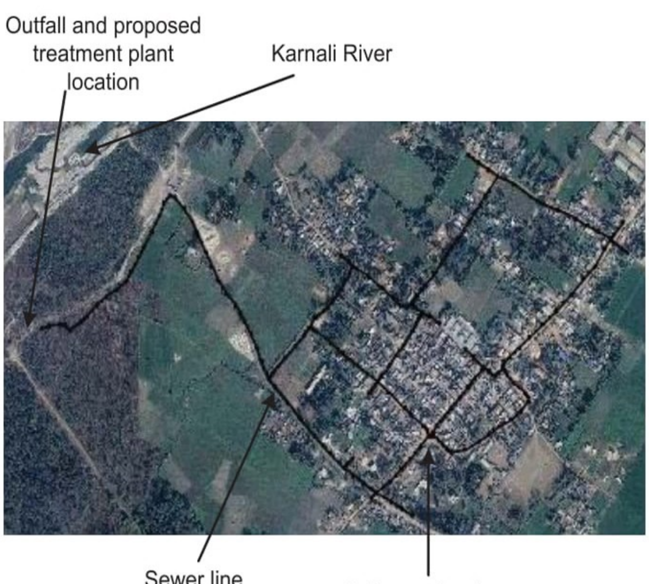

Fig. 1 Sewer layout

IV. Objective function

Whenever a sewer system is to be designed the important parameters that are to be considered are cost optimal and sufficient head availability from outfall point to the treatment plant units. The topography of the land is challenging in terms of maintaining head at the proposed treatment plant site. Therefore objective of this design is to minimize excavation depth as much as possible and at the same time selection of moderate sized sewer pipes to reduce total cost of project.

V. Methodology and Design Criteria

Flow in sewer is unsteady in nature and under atmospheric pressure. Basic hydrodynamic equation used in simulating flow under the model platform is Gravity friction method-Manning's formula [3]. The sewer channels to be designed are prismatic with circular cross section and concrete material.

The hydraulic parameters such as flow, depth and velocity are representative of the middle section of channel [3].

The sewer line is designed for dry weather flow, at 25% full discharge condition which helps in accommodating storm water of average rainfall. It is assumed that only certain part of the storm water may enter to the sewer line as there is separate provision of draining street storm water by open drainage provided on the road edges. So the system can be considered as a partially combined. Design steps and constraints are presented in Table I.

TABLE I

Design steps and constraints

Design steps
1. Calculation of Sanitary sewage [4] • Sewage factor: 70% • Peak factor: 3 • Commercial factor: 10% • Per capita water demand: 85 lpcd • Ground water infiltration: 0.1 lps/ha/day • Design period: 20 years
2. Manhole(MH) spacing Manholes are placed when there is change in alignment, gradient, diameter of sewer, head of every trunk line and laterals. Since the terrain is flat, Manhole spacing is maintained within 30 m at most so that obstruction caused due to siltation can be easily handled [5].

3.	Calculation of ground slope from the survey data.
4.	Selection of Sewer pipe class and Diameter [6].
5.	Selection of slope in sewer section from upper MH to lower MH. • Maximum slope: 1/10 [7] • Minimum slope: 1/1000
6.	Velocity constrain: V_{min}: 0.45- 0.6 m/s [8], V_{max}: 3m/s [7].
7.	Average available clear cover: Minimum 2m.
8.	Percentage full constrain: 25%
9.	Provide drop manhole for more 0.6 m elevation difference [5].

VI. Results and discussions

Design of sewer network on SewerCAD platform is efficient as the model has several options. After setting design constrains mentioned in Table I, SewerCAD automatically design all parts of the gravity sewer network. To analyse what-if situation under the introduction of flushing tank, two scenarios are developed. Design without flushing tank and design with flushing tank. In both alternatives, sewer pipe routes are same with 175 manholes, out of which 8 manholes are drop type, introduced to reduce earth work in excavation along branch pipes for cost effective design.

The result of two scenarios are estimated and rate analysis is done based on the District rate of Fiscal year 2074-2075 [9]

TABLE II
Comparison of results

Design Results	Without flushing tank provision	With Flushing tank Provision
Flow velocity	V_{min}-0.45m/s and V_{max}-0.74m/s	V_{min}-0.2m/s V_{max}-0.6m/s
Sewer Pipe class and Size	NP3-300,400,500	NP3-300,400,500,600
Invert level of Outfall	4.8m	1.8m
Total Project cost in NPR	102,202,919.71	71,915,952.92

A. Maintenance of flow velocity

1. *Design without flushing tank provision*: Under this option, design is performed with maximum slope as 1% and minimum slope as 0.2%. All sewer lines meet V_{min} as stipulated in Table II. There is no condition of exceeding of V_{max} as the maximum velocity attained is only 0.74m/s. This design can be considered safe in terms of problem that comes when velocity limits are not maintained such as corrosion and erosion.

2. *Design with flushing tank provision*: In this case, design is performed under more flat slope ranging from 1% to 0.1%. Result showed that starting points of sewer lines do not meet minimum velocity so flushing tanks are provided on the critical sections.

B. Sewer pipe size

1. *Design without flushing tank provision*: NP3-Hume pipe with diameter 300mm, 400mm and 500mm

2. *Design with flushing tank provision*: NP3-Hume pipe with diameter 300mm, 400mm, 500mm and 600mm

C. Invert level of outfall point

1. *Design without flushing tank provision*: In this option, there is excessive excavation volume and the invert level of outfall point is 5.3 m below ground level which is below the bed level of Karnali River.

2. *Design with flushing tank provision*: This design option yields minimum possible excavation depth with invert of outfall point being 2.4 m below ground level.

D. Total project cost

1. *Design without flushing tank provision*: Calculation based on norms and approved district rate resulted total project cost to be NPR 102,202,919.71

2. *Design without flushing tank provision*: Under this provision the total estimated cost of project is NPR 71,915,952.92

E. Trade off Analysis:

Analysis for optimized sewer network involves cost effective, technically sound and minimum excavation depth at the outfall point.

Examination of result of sewer network performed on Bently SewerCAD under two alternative scenarios gave insight that option one i.e. design without flushing provision only has one advantage of maintain minimum velocity over design with flushing tank option. Moreover, the problem of unmet minimum flow velocity is pronounced only during lean season flow and this can be prevented by providing flushing tanks of appropriate sizes. The major disadvantage of option one is that invert level at outfall point 4.8 m below ground level. In case of flat terrain, ground water level is quite high so high depth of excavation is directly related with the problem of ground water intrusion which hampers workmanship.

Therefore, comparison of benefits under this two design criteria shows option two i.e., design with flushing tank provision, as the most economical design.

VII. Conclusions

Design of sewer network in Bentley SewerCAD is extremely efficient as the platform allows design under different criteria and scenarios. With help of this model, Rajapur sewer network is designed and analysis showed how to design optimal sewer network in flat terrain that meets technical specification and at the same time is cost effective.

Flat terrain was the main challenge for design. It is thus important to look for several options and introduce ancillary structures that will offset problems caused by design constrain limitations.

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