International Journal of Environmental Sciences
Vol. 9 No. 2 (July-December, 2023)

http://www.theaspd.com/ijes.php

Storm Water Network Design using Sewergems – ITPL Road, Mahadevapura Bangalore, Karnataka, India

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Received: 13th June 2023
Revised: 17th September 2023
Accepted: 19th October 2023

Abstract: Climate change and increasing urbanization have contributed greatly to urban flooding, making it a global problem. Adequate drainage is a primary requirement for maintaining the structural soundness and functional efficiency of a road. Inadequate drainage facilities can lead to premature deterioration of the highway and the development of adverse safety conditions such as hydroplaning. This paper presents design and modeling of storm water network by the application of software SewerGEMS V8i, which allows projects to be accomplished in a short time, with high efficiency. This paper presents the study and analysis of sewerage system for the ITPL Road, Mahadevpura situated in Bangalore, Karnataka. The study is on hydraulic design consists in the computation of the transit and total flow and hydraulic modelling for network pipes diameters or slopes. The network consists of pipes of varying diameters, manholes and outfall. SewerGEMS offers a full range of possibilities for the designer to draw, label, dimension and plotting the drawings of the sewage networks. With Bentley SewerGEMS v8i, it is possible to analyze the working of the network for certain years of return period.

Keywords: SewerGEM, Storm Network, Drainage Network, Highway Drainage

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1. Introduction

Drainage is the natural or artificial removal of a surface's water and sub-surface water from an area with excess of water. Drainage design involves providing facilities that collect, transport and remove storm water from the highway. Storm water in urban areas was traditionally managed by designed sewer systems for the prevention of the collection of excess water on urban surfaces and the reduction of risk to people, health, property, society and the natural and built environment.

The capital city of Karnataka, India, has faced several challenges related to road flooding during the monsoon season. Increasing urbanization has led to significant changes in the natural systems. These changes include alterations in the hydrologic flow regime as well as shifts in the chemical and biological makeup of storm water runoff from these developing areas [1].

As an area is developed, the natural ability of the catchment to withstand natural hydrologic variability is removed. Infiltration capacity is decreased due to the increase in impervious surface and disrupted native soils and vegetation. Natural retention and detention capabilities of a catchment are removed through channelization of natural waterways and the installation of formal drainage systems such as pipes and gutters.

Storm Water Networks are an important part of the infrastructure of any society. The main purpose of providing the Storm Water Networks is to carry away rainwater from a municipal area in such a way that it does not cause any public health related problems. A Storm Water Network is just a advanced action of water supply network. In respect of this view, many research works are being done to design a effective Storm Water Network with the given constraints and guidelines. These difficult problems can be solved by using the computer software SewerGEMS V8i.

This paper is to provide optimum design of urban storm water drainage systems considering the study of lowest point location to collect runoff water received from road integrated road network drainage system Identification of potential strategies and design considerations that can be applied in design of storm water network

2. Method

2.1 Problem Statement

Indian road network is consisting of expressways length is 4067 km, National highway length is 1,44,634 km, and state highway length is 1,86,908 km length. Bangalore urban itself we have 10,200 kilometers road length [2]. During normal, medium & high rain fall periods, 85% of runoff water which is collected by road drainage/storm water drain is getting wasted because of improper integrated road drainage systems [3]. Bangalore alone receives rainfall of 1,500 mm in 2021. During the monsoon season, Bangalore experiences heavy rainfall, which can overwhelm the city's drainage systems and lead to waterlogging on roads. Where the area in Bangalore Mahadevapura Zone gets flooded every year, where ITPL road is regularly affected due to inadequate road design. From well-planned integrated road drainage systems, we can use Approximately 5 TMC of runoff water in Bangalore city itself [3]. It is most feasible solution for water scarcity in urban & surrounded districts.

2.2 Storm Water Network Design

Preliminary Study

The concept of a road integrated network suggests that the planning and design of roads take into consideration the overall transportation and design constrain ecosystem to ensure efficient, safe, and sustainable mobility for people and goods. This might involve considerations such as creating designated proper storm water network, lanes for buses or bicycles, designing intersections with pedestrian crossings, implementing smart traffic management systems, and integrating with public transit hubs.

The first step in the study is to analyse the topography of the road network and the surrounding area. This includes identifying the high points and the low points of the terrain which are identified by the help of the contour lines through Civil 3D software. The lowest points are of particular interest as they provide potential locations for collecting and channelling the runoff water. Based on the crucial aspect of the study of the contour lines noting the high and low points involving Civil 3D software to simulate how water flows through the road network during rainfall events. The modelling takes into account various factors such as the road's cross-sectional shape, road gradient, surface materials, and the presence of drainage structures like culverts, catch basins, or ditches.

The next step is to study the road and ground profile where the existing ground surface of Mahadevpura ITPL road located at latitude 12°58'3.31"N and longitude 77°42'50.79"E with the ground elevation of 903.62 Meters. The study is performed for 1.19kms stretch taking into account the long fall, crossfall, contour lines, and elevations of that particular location in Autodesk civil 3D. Identification of the balanced road or super elevated road is done on the basis of the crossfall. To check whether the road is in cutting or on embankment contour lines, Tadpoles and crossfall of the road was used. The surface file compatible to AutoCAD, Civil 3D represents the road network of the ITPL Road supported with contour lines which inturn provides the high and low points of the street. With the help of contour line the flow direction of the run off could be identified and according to which low point is identified and the Storm Water Network is laid.

2.3 Placing of Network

The Mahadevpura Zone is one among 8 Zones that is flooded every monsoon where ITPL Road is more subjected to flooding. As per the high and low points as shown in Figure 1 the pipe network for storm water collection is laid alongside the lowest point of the road. The storm water is collected through gullies as collection system conveyed through pipe network with 90m spacing for manhole to manhole.

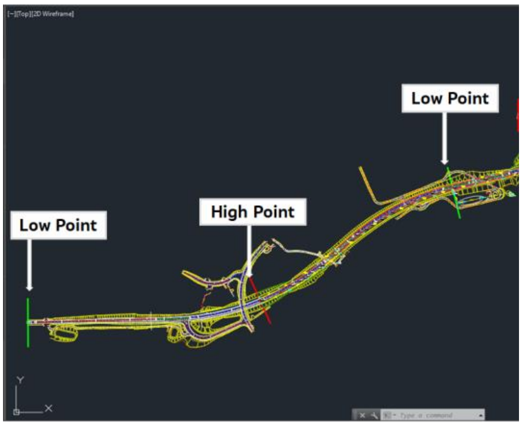

Figure 1: ITPL Road Layout with Contour Lines

The network laid is represented in the Figure 2, beginning from the highest elevation in the road network reaching towards the lowest point. The complete network further connected to the nearest outfall in the region. The pipe network is in the Figure 2 provided with manholes of 90m Manhole to Manhole spacing. The pipe and manhole diameter are assigned as per the volume determined from the annual rainfall data.

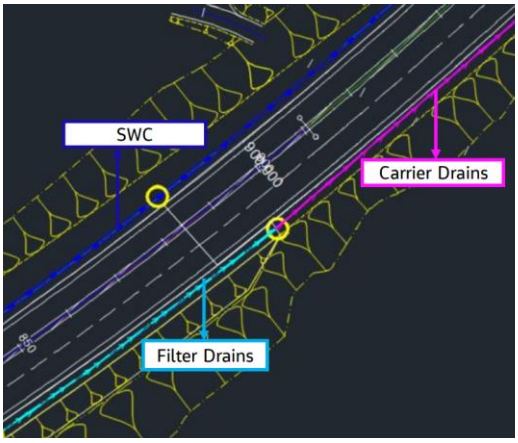

Figure 2: Storm Water Network

2.4 Design Constrains

Designing a stormwater network involves planning and engineering systems to manage rainfall and stormwater runoff efficiently and sustainably within a community or urban area. To identify potential strategies and design considerations for stormwater networks, several factors need to be taken into account.

Understand the local rainfall patterns, intensities, and variations. The design of the stormwater network should be capable of handling different storm events while considering the potential impact of climate change on rainfall patterns. For this particular study we have considered rainfall data of Mahadevpura Zone for below return periods considering the critical rainfall event. Rainfall is the primary source of inflow into stormwater and sewer systems. Table 1 provides the rainfall data, SewerGEMS can calculate the amount of water entering the system during rainfall events. This information from Table 1 is essential for accurately modeling the flow rates and volumes in the network.

Table 1: ITPL Road, Mahadevpura Zone

Return Period	Rainfall (mm)	Rainfall Duration (hr)	Rainfall Intensity (mm/hr)
1 Month	12.65	24	0.5271
2 Month	13.3	24	0.5542
5 Month	46.65	24	1.9438
1 Year	116.35	24	4.8479
2 Year	134.76	24	5.6150
5 Year	168.62	24	7.0258
10 Year	226.1	24	9.4208
25 Year	228.09	24	9.5038
50 Year	270.17	24	11.2571
100 Year	295.34	24	12.3892

Source: Author's findings

The Design of storm water network is such that the all the conduits placed should be working under the existing gravity. The minimum velocity provided is 0.75 m/s to enhance self -cleansing and maximum 1.5m/s to avoid water hammering effect. To achieve these velocity the pipe slope maintained is 0.005m/m to 0.1 m/m.

The design criteria assigned for each Pipe and the Manhole, where the hydraulic parameters are maintained as per the given minimum and maximum as per the IRC SP: 42-2014 standards. The flow direction of the runoff is also symbolized. Care should be taken to ensure that manhole diameters are larger than incoming and outgoing pipes throughout the network. Along with this there should always a cover depth of 1.2m is to be mandatorily maintained between the soffit pipe network and road surface to avoid any external damage due to vehicle load.

2.5 Validating & Model Networking

Once the Storm Water Network is aligned, then the network should be validated to check for any errors in the design. Once the network is validated the system can be checked for the working of the working of network for 2, 5 and 10 years return period. Once the network is complete the performance of the network is obtained in the form of Flex Table which is mentioned in Table 2.

Table 2: Pipe Flex Table

Label	Length (Scaled) (m)	Diameter (mm)	Flow (m3/s)	Velocity (m/s)	Area (m2)	Depth (m)	Invert Start (m)	Invert Stop (m)
CO-1	57.23	100	1.63	1.2	0.4	0.48	903.28	903.58
CO-2	15.23	250	1.47	1.3	0.1	0.28	903.58	902.98
CO-3	100.25	300	1.36	0.75	2	1.2	902.98	902.74
CO-4	40.04	400	0.56	0.8	1.4	1.2	902.74	902.48
CO-5	20.81	400	1.35	1.5	0.4	0.46	902.48	902.37
CO-6	8.74	500	2.36	0.82	0.6	0.53	902.37	902.32
CO-7	51.97	600	2.14	1.35	0.6	0.47	902.32	902.24
CO-8	108.75	600	1.56	2.1	0.6	0.33	902.24	902.84
CO-9	52.18	700	0.78	2.4	0.3	0.77	902.84	902.52
CO-10	59.51	700	0.77	0.54	1.1	0.89	902.52	902.31
CO-11	39.56	800	1.14	1.26	0.2	0.97	902.31	902.28
CO-12	53.54	800	0.58	1.54	0.7	0.67	902.28	901.97
CO-13	54.44	900	1.26	1.32	1.1	0.98	901.97	901.63
CO-14	221.43	900	1.35	1.56	1.1	0.94	901.63	901.54
CO-15	23.36	1200	0.79	1.78	1.1	0.58	901.54	901.32
CO-16	74	1200	1.15	1.64	0.4	0.75	901.32	902.54
CO-17	48	1400	2.31	1.58	0.8	0.6	902.54	902.67
CO-18	52.15	1400	2.64	2.65	1.1	0.84	902.67	902.47
CO-19	31.5	1400	1.54	2.84	0.8	0.93	902.47	903.51
CO-20	121.75	1400	1.23	2.64	2	1.05	903.51	903.64
CO-21	56	1400	1.16	2.54	1.6	1.43	903.64	903.75

Source: Author's findings

All the Pipe are denoted as Conduit "CO" numbering it from upstream to downstream. The length of the pipe is given as per the drawing and its placement. The Pipe diameter mentioned in Table 2 is dependent on the flow and velocity which varies as per the annual rainfall provided. The Storm Water Network can be examined for any annual rainfall data to know its performance. Whereas here all the network is design period is of 25 years.

The Manhole Flex Table 3 provides all of the manholes hydraulic parameters, significantly, the "Is Overflowing" column in the manhole flex table demonstrates how the network is operating.

Table 3: Manhole Flex Table

Label	Elevation (Ground) (m)	Diameter (mm)	Flow (m^3/s)	Velocity (m/s)	Depth (m)
MH-1	903.21	1000	1.5	1.1	0.27
MH-2	903.27	1000	1.24	1.64	0.36
MH-3	903.28	1000	1.23	1.54	0.42
MH-4	903.22	1000	1.25	0.56	0.48
MH-5	902.79	1000	1.36	1.57	0.56
MH-6	902.54	1500	1.54	0.69	0.61
MH-7	902.05	1500	2.14	1.54	0.78
MH-8	902.71	1500	1.64	2.14	0.71
MH-9	902.35	1500	1.35	1.39	0.75
MH-10	902.82	1000	0.77	0.54	0.89
MH-11	902.89	1000	1.64	1.64	0.93
MH-12	902.86	1500	1.78	1.77	1.02
MH-13	902.75	1500	1.26	1.64	1.05
MH-14	902.84	1000	1.46	1.47	0.93
MH-15	903.78	1000	1.54	1.69	0.38
MH-16	903.35	1500	0.64	1.45	0.98
MH-17	903.91	1000	0.78	1.33	0.83
MH-18	903.47	1000	0.65	1.92	0.25
MH-19	903.45	1000	1.54	2.1	1.25
MH-20	903.21	1500	1.25	2.14	1.31
MH-21	903.57	1000	1.54	2.58	1.56

Source: Author's findings

If that particular area is checked then there would be floods in that specific area. In cases where there is overflowing displayed, the diameter of the pipe and manhole should be increased until they can accommodate the volume of discharge.

3. Findings and Discussions

The critical result check helps identify potential issues like flooding, surcharging, or inadequate capacity in the network, allowing engineers to make necessary adjustments and ensure that the stormwater system meets design standards, regulatory requirements, and safety criteria. It plays a vital role in verifying the functionality and effectiveness of the stormwater drainage design.

For 1 year return period the designed storm water network is performing excellent good without any flood or surcharge happening for any of the rainfall even in 1 year. For 5 year return period the designed storm water network is performing good without any flood, but for 5 years return period the condition of surcharge is acceptable. For 100 year return period the designed storm water network is performing good although there is flood risk shown where the max volume is less than 10m3 which isn't problematic.

4. Conclusion

The utilization of SewerGEMS V8i software in the Storm Network Design process proves to be remarkably efficient and user-friendly. This software simplifies the entire design procedure, making it accessible even for those with limited experience. Furthermore, the Storm Water Network system exhibits outstanding performance, ensuring the effective management of stormwater for return periods of 10, 25, and 50 years without encountering surcharge issues or posing any flood risks. The incorporation of SewerGEM software in this context facilitates the assessment of network functionality across specific years, aligning it with the corresponding runoff data for precise analysis and optimization.

This innovative network design approach holds significant promise in mitigating urban flooding challenges. By addressing these issues, it not only enhances the safety of road users but also extends the lifespan of critical road infrastructure components. Consequently, it represents a holistic solution that combines efficiency, safety, and infrastructure durability to tackle urban flooding problems head-on.

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