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Research Article

Assessment of drainage capacity of a surface drain in Rajshahi, Bangladesh

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ABSTRACT

The drainage capacity of a community is essential for promoting environmental resilience, effective water management, and fostering a healthy urban lifestyle. The surface drains in Rajshahi City receive a mix of waste, including sanitary wastewater, stormwater runoff, and solid waste from roadsides and households. To improve the drainage facilities of Rajshahi, some new drains have been constructed. This study considered a recently constructed drain in the Rajshahi City Corporation (RCC), running from Talaimari to Chowddopai. The primary objective of this study is to assess the drainage capacity of this drain during both dry and monsoon seasons, ensuring its capability to contain the generated waste. Additionally, the investigation encompasses observing the sludge depth, and clear space of the drain. A field survey was conducted, employing a measuring rod and scale to precisely measure the depth, width, and sludge accumulation. The results show that the total volume of the drainage system is 117670 ft^3, while the total volume of solid deposition is 6287.60 ft^3. Solid deposition occupies 95% of the entire drainage path, leaving 5% as clear space. The total solid deposition volume represents approximately 5.34% of the total volume of the drainage system (6287.60 ft^3 of 117670 ft^3). This study revealed that during typical rainfall intensity in Rajshahi City, the portions of drains from Talaimari to Octroimor and from Rajshahi University main gate to Chowddopai have sufficient open space to prevent water overflow, but the capacity of the drains in the portion between Kajla and Rajshahi University main gate is inadequate.

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INTRODUCTION

Efficient drainage infrastructure is pivotal for mitigating the adverse impacts of heavy rainfall and preventing flooding, which can endanger lives, disrupt livelihoods, and cause extensive damage to property and infrastructure. Water, in any form – groundwater, surface water, or rain runoff – is a major contributor to road failure and damage [1]. So, a drainage system that includes the pavement and the water handling system must be properly designed, built, and maintained [2]. The purpose of drainage facilities is to ensure the timely removal of surface water runoff and sewage from large, impermeable areas [3]. Different drainage systems have varying effects on drainage capacity. Sustainable drainage systems (SuDS) improve retention and management of runoff quantities and flow rates by concentrating on slower processes like evapotranspiration and infiltration [4]. Runoff rates are impacted differentially by different types of SuDS; vertical construction in apartments results in reduced peak runoff. Runoff rates are reduced more by SuDS on existing infrastructure than on undeveloped land [5]. In comparison to soak ways and infiltration trenches, the capacity down pipe SuDS tech-

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nique—which includes ponds and filter strips—can greatly increase drainage capacity in metropolitan settings, fostering effective water management and cost-effectiveness [6]. With a high starting velocity and minimal energy consumption, the vertical drainage capacity of an advanced electro-osmotic drainage board may effectively enhance drainage in extremely soft clayey ground [7]. The availability of SuDS and surface cover types can have an impact on peak runoff rates and total runoff volumes, which in turn can affect a landscape's overall drainage capacity [8]. In low-gradient landscapes, different drainage systems, such as seepage erosion and overland flow, affect drainage capacity by causing different channel development processes depending on substrate, rainfall, and relief conditions [9]. The drainage density and shape of hillslopes are influenced by several processes, including diffusive-advective transition, erosion thresholds, and land sliding. These factors affect the landscape drainage capacity, which is contingent upon environmental parameters such as rainfall and relief [10]. various drainage methods affect drainage capacity by improving soil protection, generating a groundwater reservoir, and reducing the consequences of climate change like floods and droughts [11]. The frequency and amount of stormwater flows will grow in the future, posing challenges for drainage systems [12]. Therefore, it is now urgently needed in the industry to accurately measure the drainage system's service performance and simulate its operational status [13].

Using the best drainage engineering principles, an effective drainage plan must be established to understand the drainage issues that Bangladeshi cities face [14]. Rajshahi, a prominent northern Bangladeshi city, established in 1876 as one of the first Municipalities, transitioned to Rajshahi Pourashava and finally to RCC in 1987 [15]. According to the Drainage Master Plan, Rajshahi City features primary, secondary, and tertiary drains, with 65% of tertiary, 14% of secondary, and 19% of primary drains in good structural condition. The city's management is organized into 30 wards, overseeing 132.27 km of various drain categories, originally designed to cater to the core area between the Railway line and the river Padma embankment, where the countryside elevations range from 16.75 to 18.25m[16]. The drainage pattern of Rajshahi City is still filthy despite significant yearly budgets for development and reform; this is because insufficient planning led to a failure to meet demand [17].Rajshahi City Corporation has recently taken some projects to increase surface drainage facilities in the city. Such a new drainage network has been constructed recently, in 2023, from Talaimari to Chowddopai.

A recent work on the characteristics of drainage liquid wastes and deposited drainage solids of the old drains of Rajshahi City has been conducted [18]. Now, our research focus is on these newly constructed drains, finding the physical properties of the drains and their capacity along with some other factors about this drain.

MATERIALS AND METHODS

Study Area

The study area Rajshahi, as shown in Fig.1, is situated between latitudes 24°21' and 24°25' N and longitudes 88°32' and 88°40' E. The Rajshahi City Corporation, the location of study, has given careful consideration to the city's drainage system to maintain a clean city. There are a lot of outdated drains, a lot of recently constructed new drains, and additional drain construction is ongoing. Among them, a new drainage network that begins from Talaimari and finishes at the Chowddopai primary drain has been built in front of the Rajshahi University of Engineering & Technology (RUET). In Fig. 2, the red, pink, and blue color is the path of drainage line and sky color border is the border of RUET.

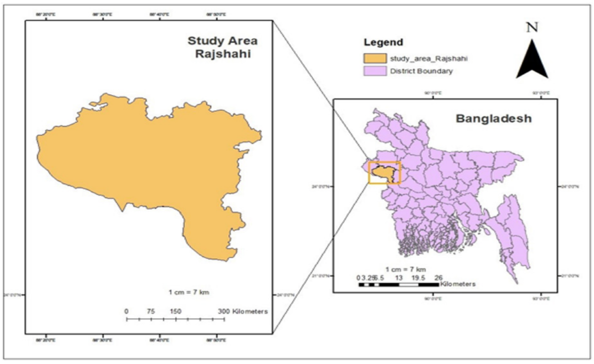

Figure 2. Drainage Network from Talaimari to Chowddopai in Google

Fig.2 shows the drain's path. We sought to determine its dimensions and capacity—that is, the amount of solid material that has already been deposited and the amount of space that may be used to convey trash to the principal drain. The image of the study area from Google Earth.

Materials

A measuring tape with a steel rod and a bamboo were used for measuring the dimension of drain shown in Fig 3 at different sections and thickness of deposited sludge at the bottom of the drain as well as the depth of flowing wastewater. The software Google Earth Pro and ArcGIS were used for preparing the route of drain and locations of data collection. The acquired data was analyzed by Microsoft Excel.

Figure 3. Materials for measuring dimension

Method

After selecting the study area and collecting materials, some points were selected for conducting a field survey. From the starting point Talaimari, points were selected at intervals of 100 meters to the endpoint Chowddopai. In Fig 4, the pins were placed in Google Earth Pro which indicates the points that were selected to conduct the field survey. The distance was approximately 2.8 km, so 28 points were selected.

Figure 4. Picture of the study area (from Google Earth Pro)

For a better understanding of the work, a drainage map was made in ArcGIS software shown in Fig 5.

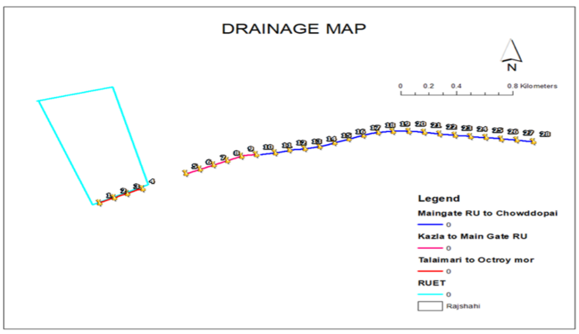

Figure 5. Data collection points

During the field survey, A rod was inserted into the bottom of the drain. After that, the rod was leveled at the opening point of the drain, and took measurements. Thus, the total depth of the drain was ascertained. Proceed in the same manner, but this time, the rod was inserted into the drain at a depth where the solid deposit's surface was still visible. Then, the rod was pointed again and the measurement was taken. Thus, the clear space of the drain was measured. After that, with the measuring tape, the width of the drain was determined. After completion of the data collection, the data was plotted in Excel and the physical characteristics of the drain has been determined.

The capacity of the drain is determined based on rainfall data of the Rajshahi City. If the clear space of the drain is available enough to hold the rainfall water, then it is considered as "Adequate" to hold rain water. In either way, the drain is termed as "Inadequate".

Equations

The actual cross-sectional area using the actual depth of the drain using the equation

$A1 = b*D$......(i); here, b=Width of the drain, and D= depth of the drain

The clear cross-section of the drain,

$A2 = b*d$......(ii); here, d=depth of clear space.

The Solid Deposition area,

$A= A1-A2$......(iii)

Solid Deposition depth, $d= A/b$

The total capacity of the drain,

$V1= A1*L$......(iv); here, L= Total length of drain =2.8km (approx.)

The available capacity of the drain $V2= A2*L$......(v)

Rainfall Calculation:

Total Rainfall volume,

$V = h * La * ba$......(vi); where, h = Rainfall depth, La = Length of catchment area and, ba= Average width of the catchment area

If, Clear space volume > Total Rainfall volume: Adequate

If, Clear space volume < total Rainfall volume: Inadequate

FINDINGS AND DISCUSSIONS

Data Collection

A total of 28 points were selected as data points from the Talaimari to the Chowddopai. Four points were selected from the Talaimari to the Octroimor. No drain was found from the Octroimor to the Kajla. From the Kazla gate to the Rajshahi University (RU) main gate, five points were selected while from the RU main gate to the Chowddopai total of 19 points were selected. All the collected data are presented in Table 1.

Table 1. Drain data

Location	Actual width	Actual Depth	Actual cross-sectional area (ft2)	Depth above solid	Area above Solid Waste (ft2)	Solid Deposition (ft2)
Talaimari to Octroimor	4'-0"	4'-7"	18.33	4'-5"	17.67	0.66
				4'-6"	18	0.33
				4'-7"	18.33	0
				4'-5"	17.67	0.66
Kazla Gate to RU Main Gate	1'-9"	2'-3"	3.94	2'-2.5"	3.86	0.08
				2'-0"	3.5	0.44
				2'-2.7"	3.89	0.05
				2'-2.9"	3.92	0.02
				2'-3"	3.94	0
RU Main Gate to Chowd-dopai	4'-0"	4'-0"	16	4'-0"	16	0
				3'-9"	15	1
				3'-9"	15	1
				3'-9"	15	1
				3'-8"	14.67	1.33
				3'-11"	15.67	0.33
				3'-10"	15.33	0.67
				3'-7"	14.33	1.67
				3'-10"	15.33	0.67
				3'-10"	15.33	0.67
				3'-9"	15	1
				3'-11.5"	15.83	0.17
				3'-7"	14.33	1.67
				3'-8"	14.67	1.33
				3'-9.5"	15.17	1.17
				3'-8.75"	14.92	1.08
				3'-7"	14.33	1.67
				3'-8"	14.67	1.33
				3'-10"	15.33	0.67
Chowddopai Primary drain	17'-0"	Actual Depth 10'-0"				

Capacity of the Drain during Dry Season

Analysis of the capacity of the drain during the dry season is presented in Table 2.

Table 2. Analysis of the capacity of drain during dry season

Zone	Total length (ft)	Total volume (ft3)	Solid deposition (sq ft)	The volume of deposition in this zone (ft3)	Volume of clear space (ft3)
Talaimari to Octroimor	984	18036.76	0.4125	405.9	17630.86
Kazla gate to RU main gate	1312	5169.28	0.118	154.82	5014.46
RU Main gate to Chowddopai	5904	94464	0.97	5726.88	88737.12
Overall Analysis	8200	117670	1.5	6287.60	111382.44

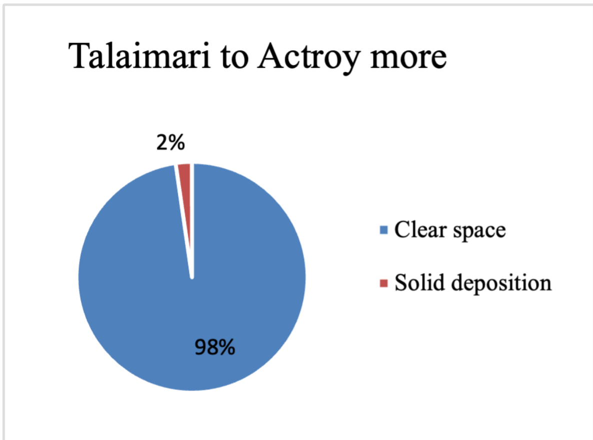

Figure 6. Clear space and solid deposition in Talaimari to Octroimor

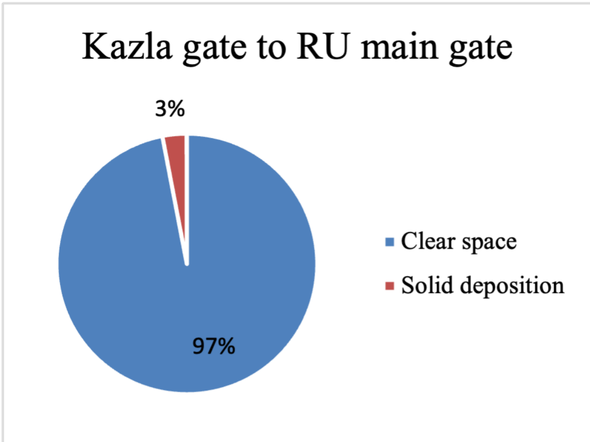

Figure 7. Clear space and solid deposition in Kazla gate to RU main gate

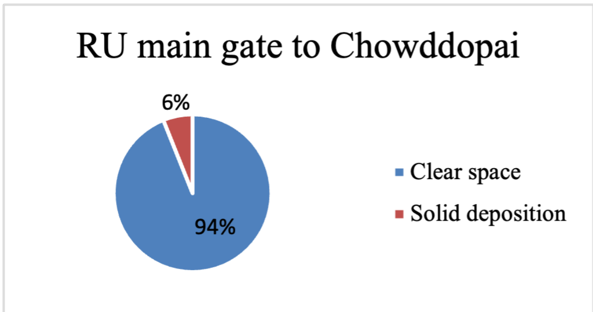

Figure 8. Clear space and solid deposition in RU main gate to Chowddopai.

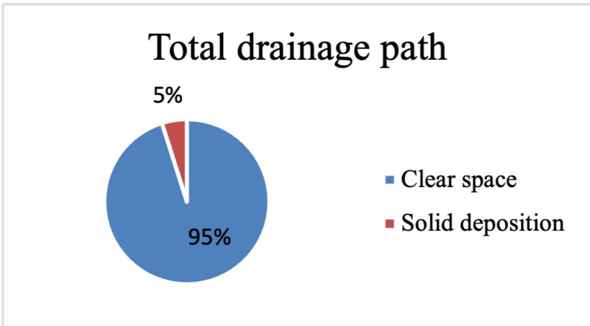

Figure 9. Clear space and solid deposition of the entire drainage path

A comparison between the volume of the clear space and the volume of the solid deposition in Talaimari to Octroimor is shown in Fig 6. A comparison between the volume of the clear space and the volume of the solid deposition in Kazla gate to RU main gate is shown in Fig 7. A comparison between the volume of the clear space and the volume of the solid deposition in RU main gate to Chowddopai is shown in Fig 8. A comparison between the total volume of the clear space and the total volume of the solid deposition in the entire drainage system is shown in Fig 9.

Capacity of the Drain during Monsoon

Rainfall intensity According the to Bangladesh Metrological Department, the average rainfall of Rajshahi is 3.74 inches (0.31 ft). The drain passes along the road. So, for the calculation of rainwater volume, the length and width of the road have been taken using Google Earth Pro. Analysis of the capacity of the drain during the monsoon season is presented in Table 3.

Table 3. Analysis of the capacity of drain during monsoon season

Zone	Total length (ft)	Average width	Solid deposition (sq ft)	The volume of deposition in this zone (ft3)	Volume of clear space (ft3)	Adequate/ Inadequate
Talaimari to Octroimor	984			984*33.3*0.31 =10157	17630.86	Total rainfall volume < volume of clear space of drain; Adequate
Kazla gate to RU main gate	1312	66.2/2 =33.3	0.31	1312*33.3*0.31 = 13543.77	5014.46	Total rainfall volume > volume of clear space of drain; Inadequate
RU Main gate to Chowddopai	5904			5904*33.1*0.31 = 60947	88737.12	Total rainfall volume < volume of clear space of drain; Adequate

DISCUSSION

The area of solid deposition in the drain varies from 0 to 1.67 square feet. Maximum solid deposition was found between the RU main gate and Chowddopai while minimum solid deposition was found in the Kazla gate to the RU main gate. In Chowddopai, the primary drain is rooted in which has a 10 ft actual depth and 17 ft actual width. The drain portion from Talaimari to Octroy mor and the RU main gate to Chowddopai is adequate for the average rainfall of Rajshahi but From Kazla to RU main gate portion of the drain is inadequate. So, this portion of the drain should be reconstructed. A map was created in ArcGIS providing all the data collected from field surveys.

This drainage path is very promising as it has adequate width and depth as well as solid deposition is also acceptable. It is capable enough to handle rainwater runoff, road safety, property protection, and urban planning. For typical rainfall intensity in Rajshahi City, the drain between Talaimari and Octroi more and between RU main gate and Chowddopai has enough open space to prevent the spilling of water, however, the drain between Kazla and Ru Main Gate does not.

CONCLUSIONS

In this paper, one of the newly constructed surface drains has been considered. The depth of sludge deposition, clear space, and drainage capacity of the Talaimari to Chowddopai drainage network in RCC is calculated by conducting a field survey. As it is a new drain, the capacity of the drain is in satisfactory condition. The sludge accumulation is quite low as it has a low amount of solid deposition. To keep good performance of the drain, sludge should be kept minimum. For this reason, the drain should be cleaned at regular intervals, so sludge accumulation can be under control. Solid deposition is comparatively more in RU's main gate to the Chowddopai area. Still, it is capable of flowing rainwater. But the dimension of the drain from Kazla to RU main gate is less. So, it is inadequate for the average rainfall of Rajshahi.

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DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

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