

HYDRAULIC EVALUATION OF ROAD SIDE DRAINAGE SYSTEM IN MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY YOLA, ADAMAWA STATE, NIGERIA

T.S.K. Tya* and E Akoh

Department of Agricultural and Environmental Engineering, School of Engineering and Engineering Technology, Modibbo Adama University of Technology, Yola.

*Corresponding author: tsktya@gmail.com

ABSTRACT

Hydraulic evaluation of roadside drainage is very vital to ascertain the effectiveness of the structure for flood control in an area. The Road has been seriously damaged due to the presence of matured trees too close to the drains which causes the drain walls to breakdown. Thus there is the need to evaluate the hydraulic performance of the system and determine the system efficiency as it is being used. Rational formula and Manning's formula were used to determine the catchment peak discharge and channel discharge, respectively. A survey study of the area was carried out for the purpose of determining the slope of the drainage area. The annual rainfall data of the area was used to obtain the rainfall intensity. Results obtained showed that the slope of the drainage area was 0.023 with rainfall intensity of 17.81 mm/h. Catchment peak discharge and channel discharge were 1.58 m³/s and 1.29 m³/s, respectively. The channel hydraulic radius was determined as 0.45 m, this value obtained implies that the efficiency of the channel was low which lead to the overflow experienced during rain fall in the area. Therefore, this study recommends improvement in the integration of road side drainage structure. Also improvement in solid waste management system is required to avoid flooding as a result of blockage of drains. This requires proper maintenance and cleaning with suitable measures to be taken in order to make the roadside drainage structures serve for the intended purposes sustainably to the stakeholders.
KeyWords: hydraulic, evaluation, road side, drainage, system, Yola

1 INTRODUCTION

Provision of adequate drainage is of paramount importance in road design and cannot be over emphasized. The presence of excess water or moisture within a roadway adversely affect the engineering properties of materials with which it was constructed. When it rains, part of the rain water flows on the surface while part of it percolate through the soil mass as gravitational water until it reaches the ground water. Some water is retained in the pores of the soil mass and on the surface of the particles which cannot be drained by normal gravitational methods. It is required that the surface water from the carriage way and shoulder should effectively be drained off without allowing it to percolate to sub-grade. The surface water from adjoining land should be prevented from entering the road way. The side drain should have sufficient capacity and longitudinal slope to carry away all the surface water collected [1]. According to [2] cut or fills failure, road surface erosion and weakened sub-grades followed by a mass failure are all product of inadequate or poorly designed drainage. Many drainage problems can be avoided in the location when drainage design is most appropriately included in alignment and gradient planning. The importance of this work is to avert the persistence damage on the drainage channels caused by silting, blockage of the channels and tree roots growth in the channels which eventually damage free drainage system in the University. This problem may lead to flooding, ponding and water logging of the road surface and prevent the bearing capacity of the pavement. Thus the objective of the research work was to evaluate hydraulic performance of the system and determine the efficiency of the system as it is being used to ascertain the performance of the system.

1.1 Drainage systems

Drainage is a natural or artificial removal of surface and subsurface water from a given area within a given period of time to maintain water table to a reasonable depth. Many agricultural soils need

drainage to improve production or to manage water supplies [3]. According to [4], it is essential that adequate provision is made for road drainage to ensure that a road pavement performs satisfactorily. Proper drainage helps in maintaining water table to a reasonable depth so that water cannot rise above the natural ground by capillary action. It improves sanitary condition of the area, controls malaria and weeds. In addition, [5] stated that drainage is an important feature in determining the ability of a given pavement to withstand the effect of traffic and environment. While planning and executing the work, the contractor has to take all adequate precautions against drainage system to keep the road free from water. An increase in moisture content decreases the strength of the pavement (bad drainage causes the premature failure of the pavement).

1.2 Efficiency of channel drainage system

The channel efficiency is the ability of water movement and sediments in the channel. A channel is described as efficient if the area of water in the cross section is large compared with the bed and the banks of the channel; this can be determined by using hydraulic radius, 'R' which is the ratio of cross sectional area, 'A' to wetted perimeter, 'P'. Channel efficiency is dependent on hydraulic radius, thus the greater the hydraulic radius the greater the efficiency of the channel and the more volume of water the channel can carry [6].

1.3 Hydrological analysis

Hydrological analysis of the area to be drained is an essential element in the design of roadway drainage. This is because it supplies the information on runoff and stream flow characteristics which are used as the basis for the hydraulic design. In this process the design flow was established by selecting the proper combination of rainfall and runoff characteristics that can be reasonably expected to occur. This is further restricted by establishing an interval of time in frequency period as the basis for design. The design criteria would then be the discharge capacity to be carried by the design structure with no discharge or a limited amount of discharge to be equaled or exceeded on the average of one during a design [7].

Rational method is an empirical relation between rainfall intensity and peak flow that is widely accepted by hydraulic engineers. The Rational method is usually expressed as [8];

$$: \quad Q = \frac{CIA}{360} \quad (1)$$

where; Q=Quantity of runoff (m³/s), C= Coefficient of runoff, I= Intensity or rate of rainfall (mm/h), A= Area of the watershed (ha)

1.4 Components of the rational method

1.4.1 Area (A)

The area, A, draining to any point under consideration in a storm water management system must be determined accurately. Drainage area information should include: i. Land use - present and predicted future - as it affects degree of protection to be provided and percentage of imperviousness. ii. Character of soil and ground cover as they may affect the runoff coefficient. iii. General magnitude of ground slopes which, with previous items above and shape of drainage, area, will affect the time of concentration. This includes information about individual lot grading and the flow pattern of runoff along swales, streets and gutters [9].

1.4.2 Runoff coefficient (C)

The runoff coefficient is expressed as a dimensionless decimal that represents the ratio of runoff to rainfall. Except for precipitation, which is accounted for in the formula by using the average rainfall intensity over some time period, all other portions of the hydrologic cycle are contained in the runoff coefficient. Therefore, runoff coefficient includes; interception, infiltration, evaporation, depression storage and groundwater flow. The variables needed to estimate runoff coefficient should include soil type, land use, degree of imperviousness, watershed slope, surface roughness, antecedent moisture condition, duration and intensity of rainfall, recurrence interval of the rainfall, interception and surface storage. The use of average runoff coefficients for various surface types is common. However, runoff

coefficient is assumed to be constant although the coefficient will increase gradually during a storm as the soil becomes saturated and depressions become filled [9].

1.4.3 Rainfall Intensity (I)

Determination of rainfall intensity for use in the Rational Formula involves consideration of three factors which includes; i. Average frequency of occurrence, ii. Intensity-duration characteristics for a selected rainfall frequency and iii. The rainfall intensity averaging time, T_c . The critical storm duration that will produce the peak discharge of runoff is the duration equal to the rainfall intensity averaging time. The average frequency of rainfall occurrence used in the design of the storm water system theoretically determines how often the structure will fail to serve the protective purpose for which it was designed. The rainfall intensity averaging time, T_c , is usually referred to as the time of concentration. However, rainfall intensity averaging time more accurately defines the reason for and the use of this variable. T_c is not the total duration of a storm, but is a period of time within some total storm duration during which the maximum average rainfall intensity occurs. It is computed by summing all the travel time for consecutive components of the storm water conveyance system [9]. The time of concentration is related to the length and slope of the catchments expressed [10] as;

$$T_c = \frac{L^{0.77}}{3000S^{0.5}} \quad (2)$$

where; T_c = time of concentration (hr), L = length of the catchments (m), S = slope of the catchment (dimensionless)

1.5 Hydraulic Evaluation of Drainage System

Drainage systems must adequately convey peak storm water flows during its design life. Evaluation of the drainage system requires detailed maps of the drainage areas, catchment basins, storm drains, underground conveyance systems, and open channels. Information required for hydraulic evaluation of the drainage systems includes the following; i. dimension and shape of the conveyance structures; ii. the conveyance structure materials, iii. the storm drain inlet type and dimensions, iv. the surface or finished grade elevations and v. the flow line or invert elevations and flow capacity of systems [11].

2 STUDY AREA

The research was carried out at the Modibbo Adama University of Technology Yola along the road and the drainage channel from CEMIT junction to Usman Nagoggo T-junction (Figure.1). The area is located between latitude $9^{\circ}11'$ and $9^{\circ}33'$ N and longitude $12^{\circ}21'$ and $12^{\circ}49'$ East. The area has two major seasons; the rainy and the dry season. The rainy season lasts from the beginning of May to the end of October, while the dry season lasts mainly from November to the end of April. The driest months are January and February when the average minimum relative humidity is 13%. This is mainly due to the prevalent dry and desiccating north-east trade winds. The wettest months are August and September with average annual rainfall of 972 mm. Temperatures in the area vary; the hottest month is April with monthly average maximum temperature of 39.7°C , while the coldest months are December and January with minimum average temperatures of 16°C [12].

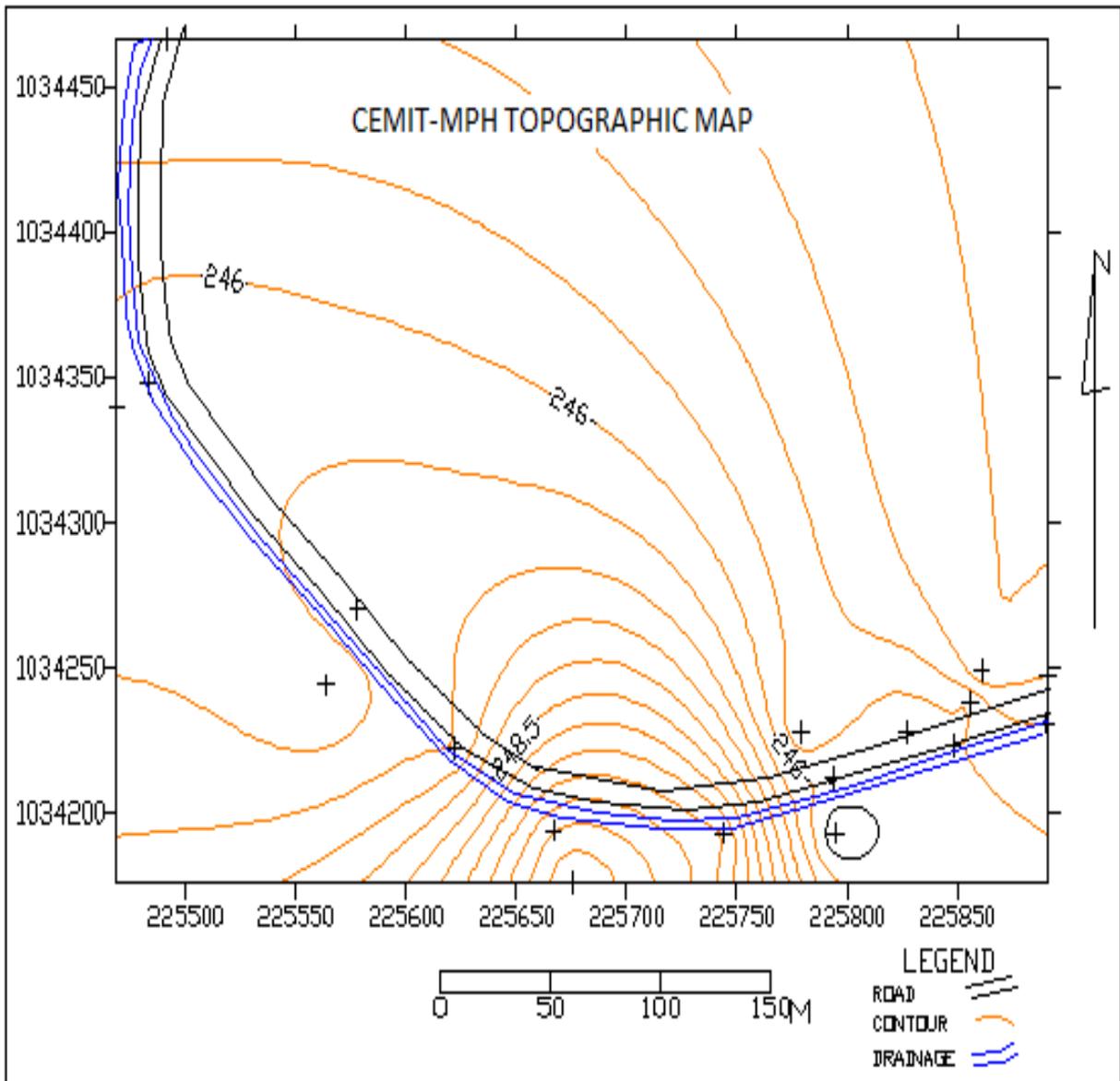


Figure 1. Map showing the road and the drainage line from CEMIT junction to Usman Nagoggo T-junction in MAUTECH, Yola

3. MATERIALS AND METHOD

3.1 Determination of the drainage area contributing runoff

From topographic map, scale 1:5000, (Figure 1). 1cm in plan correspond to 5000cm Available land use 11.76cm. Drainage area contributing to runoff = 5.88 km.

3.2 Determination of rainfall intensity (I)

The rainfall intensity was obtained from the rainfall data for 26years (1987-2013) return period. This involves the use of the rainfall intensity duration curve for Yola. To use the curve, the time of concentration (T_c) has to be equal to the duration of rainfall. Mean rainfall intensity was obtained as $I = 17.81 \text{ mm/h}$.

3.3 Determination of runoff coefficient (C)

The runoff coefficient, C, in Equation 1 is a function of the ground cover and a host of other hydrologic abstractions. It relates the estimated peak discharge to a theoretical maximum of 100% runoff. Typical values for C are given in Table 1. If the basin contains varying amounts of different land cover or other abstractions, a composite coefficient can be calculated through areal weighing as follows:

$$\text{Weighted } C = \Sigma (C_x A_x) / A_{\text{total}} \tag{3}$$

where; x = subscript designating values of incremental areas with consistent land cover. Coefficient of runoff was determined from runoff coefficient simplified Table for typical situations. The channel draining surface runoff from the residential development, roofs and green areas. Roofs = 60% C = 0.6, Roadway = 5% C = 0.1 and Green areas = 35% C = 0.3, thus the Design C = 0.7

Table1. Rational method runoff coefficients [9]

Ground cover	Runoff coefficient, C
Business areas	0.05 - 0.95
Cultivated land	0.08 - 0.42
Green areas	0.12 – 0.62
Residential areas	0.3 – 0.75
Roofs	0.7 – 0.95

3.4 Determination of time of concentration (T_c)

The time of concentration is related to the length and slope of the catchment area and it is determined by equation 2. Slope determined was from survey result, S = 0.023. Total length of catchment, L = 588 m. Concentration time, T_c = 1.76 hr.

3.5 Determination of drainage area (A)

This involved the use of topographic map of the area under study (CEMIT junction-MPH) and it was calculated as, A = 123151.8m².

3.6 Determination of runoff

The runoff computation was determined using the Rational Formula .as given in equation 1 and Q was obtained as 1.58 m³/s

3.7 Determination of drainage channel discharge

Field measurement was carried out using measuring tape to obtain the length, sizes and diameter of the existing drainage channel. Manning’s equation was used to estimate the flow in the channel for the given depth of 0.44m and channel slope of 0.023 and n = 0.013. Manning’s formula is expressed as;

$$Q = \frac{A \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}}{n} \tag{4}$$

where; Q=discharge (m³ /s), n=roughness coefficient of the channel, a=wetted area (m²), P=wetted perimeter (m), S=slope of the water surface. Thus, Q = 1.29 m³/s.

3.8 Determination of drainage channel efficiency

A channel is described as more efficiency if there is a large area of water in the cross section compared with the length of the bed and banks. The efficiency was determined using hydraulic radius, R [4];

$$R = \frac{A}{P} \tag{5}$$

where; A = cross sectional area (m²), P = wetted perimeter (m). Therefore, Hydraulic radius, R = 0.45m

3.9 Determination of drainage channel flow velocity (V)

Flow velocity was determined using Manning’s equation expressed as;

$$V = \frac{R^{2/3} \times S^{1/2}}{n} \tag{6}$$

where; V = flow velocity (m/s), R = hydraulic radius (m), S = slope of the channel, n = Manning roughness $V = 6.85$ m/s.

4 RESULTS AND DISCUSSION

4.1 Hydraulic parameters of existing road side drainage system

Table 2 present the existing parameters of the drainage system in the study area. Table 2 indicates that the length of the existing drainage system was determined as 0.588km on the scale of 1:5000. Table 2 also shows the rainfall intensity, the drainage rise, drainage slope, and time of concentration, catchment area, and discharge of the drainage channel in the study area with values of 0.65mm/hr., 251m, 0.023, 1.76 hr, 123151.8 m², and 1.58 m³/s, respectively. The result revealed that the drainage channel (CEMIT – MPH) was constructed on 0.023 slope with maximum discharge of 1.58 m³/s and rainfall intensity of 0.65 mm/hr. It was observed that trees are mostly between 1-2m away from the drain wall which resulted in the breakdown of the drainage system due to roots growth.

Table 2. Parameters of the drainage area based on topographic map of the area

S/N	Parameters	Values
1	Drainage length, L	0.588km
2	Rainfall intensity, I	17.81 mm/h
3	Runoff coefficient, C	0.7
4	Drainage rise, r	251m
5	Drainage run, R	259.5m
6	Drainage slope, S	0.023
7	Concentration time, Tc	1.76 h
8	Catchment area, A	123151.8m ²
9	Catchment runoff discharge, Q	1.58 m ³ /s

4.2 Measured hydraulic parameters of the road side drainage system

Table 3 shows the parameters of the channel section with bottom width and flow depth of 0.42m, 0.44m, respectively. The drainage cross sectional area which is a function of the bottom width and flow depth was also shown in Table 3 and has a value of 0.189 m². Furthermore, Table 3 shows that the drainage channel discharge was recorded as 1.29 m³/s while the flow velocity value of 6.85 m/s was obtained when the hydraulic radius of the channel was 0.45 m. The hydraulic radius valued 0.45 m determined for the experimental area is small which implies low channel efficiency which is in line with [4]. Table 2 and Table 3 revealed that the catchment peak discharge of the area was estimated to be 1.58 m³/s using rational formula while using Manning’s formula, channel discharge was determined as 1.29 m³/s. Statistically, using t-test, it was observed that there was no significant difference between the discharge value determined using rational formula and Manning’s formula at 5% level of significance for the study area. The results obtained in this study revealed that the runoff experienced in the study area during rainfall period in recent time was due to small hydraulic radius and high flow velocity that the channels could not contain in the area. Thus, there is the need to improve on the hydraulic parameters of the drainage channels in the study area for efficient performance and control runoff experienced in the area during rainy season.

Table 3. Measured parameters of the drainage channel

S/N	Parameters	Values
1	Bottom width, b	0.42 m
2	Flow depth, d	0.44 m
3	Drainage cross sectional area, A	0.189 m ²
4	Wetted perimeter, P	0.42 m
5	Drainage (channel) discharge, Q	1.29 m ³ /s
6	Hydraulic radius, R	0.45 m
7	Channel Flow velocity, V	6.85 m/s

5 CONCLUSIONS

This study was conducted to evaluate hydraulic and efficiency performance of drainage channel using rational formula and Manning's formula to determine the catchment peak discharge and channel discharge, respectively. A survey study of the area was carried out for the purpose of determining the slope of the drainage area. The annual rainfall data of the area was used to obtain the rainfall intensity. Thus it can be concluded that; The slope of the drainage area was 0.023 with rainfall intensity of 17.81 mm/h. Catchment peak discharge and channel discharge were determined as 1.58 m³/s and 1.29 m³/s, respectively. The channel hydraulic radius was determined as 0.45 m which resulted to low efficiency of the channel. There is the need to improve on the hydraulic parameters of drainage channels in the study area for efficient performance to control runoff experienced in the area during rainy season.

REFERENCES

- Latif, H.W. (2017). Drainage and design of drainage system. Department of Civil Engineering at Mehran University of Engineering and Technology. *Publish in Engineering*, 68p.
- State of Georgia Department of Transport (2016). Drainage design for high ways manual, 681p.
- Arthur, C. (1980). The encyclopedia of ancient civilizations. *Rainbed publishers*, pp. 176-178.
- Punmia, B.C. (1989). Soil Mechanics and Foundation Engineering (17th. ed.). *Madras, A sourabhand Co.*pp. 1-389.
- Jeremy Barrell (2011). Trees and Structural Damage, Supplementary Information Note to Accompanied. *The BTC 2011 RICS Presentation series*.
- Bos, M.G (1994). Subsurface Drainage systems. In: H.P. Ritzema (ed), *Drainage Principle and Application No.16*, pp. 725-798.
- Steel, E.W. and Terrence, J. (1979). Water Supply and Sewage. *John Wiley and Sons*, 17p.
- United State Department of Transportation (2013). Urban design manual. Federal high way Administration, *Hydraulic Engineering Circular No. 2, 3rd edition*, Publication No. FHWA NHI-10-009, 478p.
- Florida Department of Environmental Regulation (1988), The Florida Development Manual, A Guide to Sound Land and Water Management (Chapter 5). *Tallahassee, Florida*, 78p.
- Beadles, S.J.P. (2002) Rational method: Southern Polytechnic State University, <http://www.spsu.edu/cet/sbeadles>. Accessed on 13/05/2017.
- French, R.H. (1985) Open Channel Hydraulics. *McGraw-Hill Publishing Company, New York*, 705p.
- Adamawa Diary (2010) Adamawa State Government, Ministry of Information, Yola, pp. 11-20.