Development of Improved Drainage System for Storm Water flow at Isale koko Ilorin, Kwara State, Nigeria

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Abstract- Among areas prone to flood disaster yearly in Ilorin is Isale koko. The study involved the reconnaissance survey to ascertain the current capacity of the existing drainage in the flood disaster prone area of Isale Koko, Ilorin, Kwara State, Nigeria. The dimension of the drainage network of the area was taken at eight (8) various points and the average area of the drainage was obtained to be 0.44m². The already existing drainage in the area was divided into 3 sections for easy computations of flow value, length, depth and width. The rainfall intensity for the study area was found to be 98.49mm/hr. The rational method and Manning's equation were used for the surface runoff and the proposed drainage respectively. The peak flow of the area and maximum flow velocity in the drains were determined to be 48.46m³/s and 2.21m³/s respectively. The best hydraulic section method was employed to obtain new drainage dimensions for both rectangular and trapezoidal channels. The new designed rectangular channel had dimensions of 1.16m × 0.812m while the trapezoidal channel had dimensions of 1.43m×0.72m×0.87m. The area of both channels was obtained to be 0.67m². A comparative analysis was carried against the average area of the pre-existing drainage that showed a 53.3% increase in drainage area; proving that the current drainage infrastructure of the area is grossly inadequate. Sequel to the analysis, the trapezoidal shaped drainage was recommended for the study area.

Keywords- Drainage, Flood, Infrastructure, Runoff, Storm water

1 INTRODUCTION

Worldwide, there has been a rapid growth in the number of mortality and/or people seriously impacted by storms and floods (Aderogba, 2012; Giwa, 2007). Also, in the amount of economic damage caused, a large and growing proportion of these impacts are in urban areas in low- and middle-income nations. For instance, in Nigeria, flooding affected more than three million people in selected urban areas between 1983 and 2009. Poor urban infrastructural development and planning is likely to have been a factor in this, but even if it was not, it is a proof of the vulnerability of urban populations to floods and storms whose frequency and intensity is likely to increase in most places.

The increase in the report of flood across Nigeria in recent years shows that holistic changes must be made in the management of storm water. Throughout the past decade there has been continuous increase in the occurrence of flash floods with devastating effects within the city (Adedeji *et al.*, 2012a). Cogent factors contributing to this is the improper design of the available drainages in the city, resulting in incapacity of handling storm water; improper maintenance of drainages, steady population increase with no corresponding infrastructural provision, increase in the area of impervious surfaces that would have allowed for natural infiltration of storm water etc. (Ndoma, 2015). Storm drains play a crucial role in managing floods as they collect and transport excess runoffs to safe points of discharge. When they are inadequate and cannot perform this function, flooding is the natural result as storm water escape and spill into streets and homes causing untold damages. Hence the effective design and management of storm drains plays a crucial role in the managing of floods especially in urban centers. (Ndoma, 2015; Adeleye and Rustum, 2011; Abram 2006).

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Henderson (2004) revealed that the level of risk and vulnerability in urban areas of developing countries is attributable to socio-economic stress, aging and inadequate physical infrastructure. Indeed, according to Satterthwaite *et al.*, (2007), hundreds of millions of urban dwellers have no all-weather roads, no piped water supplies, no drains and no electricity supplies; they live in poor quality homes on illegally occupied or sub-divided land, which inhibits any investment in more resilient buildings and often prevents infrastructure and service provision. A high proportion of this are tenants, with very limited capacities to pay for quality housing – and their landlords have no incentive to invest in better-quality buildings. Most low-income urban dwellers face serious constraints in any possibility of moving to less dangerous sites, because of their need to be close to income-earning opportunities and because of the lack of alternative, well-located, safer sites (Daniel *et al.*, 2012).

Adedeji *et. al* (2012b) similarly reported that flooding is a phenomenon that sometimes has devastating effects on human livelihoods. Impact of floods is more pronounced in low-lying areas due to rapid growth in population, poor governance, decaying infrastructure and lack of proper environmental planning and management. Douglas *et al., (*2008) also reported that many of the urban poor in Africa face growing problems of severe flooding; they further buttressed the fact that increased storm frequency and intensity related to climate change are exacerbated by such local factors as the growing occupation of flood plains, increased runoff from hard surfaces, inadequate waste management and silted up drainage. It must be stated that the submissions of the above authors are the exact scenario that is obtainable in Isale Koko.

The objectives of this study were to appraise the state of the current drainage system present in Isale Koko and to design an improved drainage system to effectively manage the generated storm water of the area. The outcome of this study could be beneficial to Local, State, and Federal Governments as it will prove useful in policy formulation, implementation, monitoring and evaluation, especially on issues relating to management of storm water and flood control at Isale Koko.

2 Methods

2.1 Study Area

The area of study is Isale Koko located in Ilorin East Local Government Area of Kwara State, an area that experiences flood yearly especially during the raining season (Adeniran *et al.*,2018; Olorunfemi and Raheem 2013; Oriola and Bolaji, 2012; Salami, 2007; Olaniran, 1983). It is located on longitude 8°30′14′′N and latitude 4°33′48′′ E. It has an area of roughly about 0.82km². It is one of the residential areas of Ilorin City - the state capital. Ilorin City has a tropical climate. The climate of Ilorin comprises of the dry and wet seasons with the wet season starting around May and lasting for about four to five months. There is variability both temporally and spatially in the rainfall of Ilorin. Olaniran (2002) has reported the total annual rainfall of the area to be about 1200mm. The relative humidity of the city is 65% in the dry season and between 75 to 80% in the wet season. The mean monthly temperature of the area varies from 25°C to 28.9°C (Ajadi *et al*., 2011).

2.2 Material Design

The rainfall intensity formula developed by Salami and Sule (2009) for Ilorin was used to obtain the rainfall intensity of the area. The formula is:

$$I = 22.00\{\frac{T^{0.46}}{t^{0.40}}\}\ (\frac{mm}{hr}) \quad (1)$$

where I is the rainfall intensity (mm/hr), T is return period (years) and t is the duration (hours).

The time of concentration which is the time required for storm water runoff to travel from the most hydrologically remote point of the drainage basin to the basin outlet, where remoteness relates to travel time, not necessarily distance. This parameter was obtained using the formula:

$$t = 0.0194(L)^{0.77}S^{-0.5} \quad (2)$$

where t is time of concentration (minutes), L is hydraulic length of the watershed (meters), S is average slope of the watershed. A minimum time of concentration of 20 minutes and 10 years return period are recommended for the design (FHDM Part I, 2008).

The discharge of the area was obtained using the rational formula given by

$$Q = CIA \quad (3)$$

where Q is the discharge (m³/s), C is coefficient of runoff, I is the rainfall Intensity (mm/hr) and A is the area (m²).

The Manning's equation, Linsley *et al.*, (1992) was used to compute the size of a new drain based on the discharge obtained from equation 3 above. The manning's equation is given by:

$$Qn = AR^{2/3}S^{1/2} \quad (4)$$

where Q is peak flow (m³), A is the cross-sectional area (m²), R is Hydraulic Radius (m), S is channel slope, n = Manning's roughness coefficient.

The design parameters for the new drainage based on the calculated discharge Q was obtained using the geometric properties of open channels (both for trapezoidal and rectangular channels). From Manning's equation:

$Qn = AR^{2/3}S^{1/2}$

For maximum discharge ${dQ}/_{dA} = 0$

For least wetted perimeter ${dP}/_{dy} = 0$

For the design, the least wetted perimeter will be used for obtaining the best hydraulic section (Abdulrahman, 2007; Ganiyu, 2012). The summary of the best hydraulic sections for both the rectangular and trapezoidal channel is given in the Table 1.

It is based on all the above parameters that a comparative analysis was carried out between the areas of the pre-existing drainage and that of the newly designed drainage. This was done in other to ascertain the capacity of the pre-existing drainage in effectively managing the generated storm water of the area.

Percentage increase in drainage area =

$$\frac{old\ area - new\ area}{old\ area} \times 100\% \quad (5)$$

3 Results

The average width and depth of the pre-existing drainage were obtained as 0.85m and 0.52m respectively, giving an average area of 0.44m². The rainfall for the study area was obtained to be 98.48mm/hr while the total discharge for the area was obtained to be 48.46m³/s. The entire span of the pre-existing drainage network in the area was divided into 3 sub-sections and the discharge flowing into each section was estimated and is presented in Table 2.

The values presented in Table 3 were obtained for channel dimensions and other flow characteristics for both channel types considered via the best hydraulic section. The area obtained for the proposed rectangular and trapezoidal drainage channel based on the estimated discharge was found to be 0.67m² for both channel types; this was compared against the area of the pre-existing drainage in the area already estimated to be 0.44m² and an increase of 53.3% was obtained. This value clearly proves that the present drainage network obtainable in the study area is grossly inadequate in effectively managing the generated storm water and is a significant contributor to the floods repeatedly experienced by the residents of the area.

Table 1. The best hydraulic sections

Cross section	Area (m²)	Wetted perimeter (m)	Hydraulic radius (m)	Top width (m)	Bottom width (m)	Hydraulic depth	Sectional factor (m)
Rectangle	$2y^2$	4y	$\frac{y}{2}$	2y	2y	y	$2y^{\frac{5}{2}}$
Trapezoidal	y2√3	2y√3	$\frac{y}{2}$	$4y\frac{\sqrt{3}}{3}$	$\frac{2y}{3}\sqrt{3}$	$\frac{3y}{4}$	$\frac{3}{2y^{\frac{5}{2}}}$

Where y is the channel depth (m)

Table 2. Peak flow determination using rational formula

Section	L (m)	Slope	Area (km²)	tc (min)	I (mm/hr)	Q (m³/s)	Q add (m³/sec)	Q design (m³/sec)
1	448	0.32	0.0093	11.98	98.50	0.55	1.66	2.21
2	632	0.35	0.0188	14.9	98.50	1.11	1.11	2.21
3	399	0.39	0.0093	9.9	98.50	0.55	1.66	2.21

Table 3: Channel dimension using best hydraulic section method

Channel	L(m)	Q design (m³/s)	Slope	N	y (m)	b (m)	A (m²)	T (m)	R (m)	p (m)	d (m)	V (m/s)
Rectangular	1497	2.21	0.01	0.014	0.58	1.16	0.67	-	0.29	2.32	0.812	3.13
trapezoidal	1497	2.21	0.01	0.014	0.62	0.72	0.67	1.43	0.31	2.15	0.87	3.27

4 DISCUSSION

The results show that Isale Koko is facing a serious challenge of inadequate drainage system. The objective of drainage is to remove unwanted water from the neighborhood in a controlled and hygienic manner in order to minimize public health hazards, inconvenience to residents and the deterioration of other infrastructure. Drainage systems are constructed to ensure that storm water is transported neatly to disposal points, thereby keeping the environment well drained and free of storm water.

Ilorin, Kwara state capital has not been exempted from the devastating effects of floods, in fact over the years it has been among the worst hit (Adeniran *et al*.,2018; Olorunfemi and Raheem 2013; Salami, 2007; Olaniran 1983). The Daily Trust (2019) reported the loss of property worth millions of naira, businesses and household items and lives due to flood caused by heavy downpour of rain. It reported Harmony Estate, Akerebiata, Gerin Alimi, Isale Koko, and Kulende as affected areas among other parts of the metropolis. Of important mention was that residents of these areas attributed the flood to narrow drainages, which they said quickly filled up by the downpour, thus flooding the affected homes and shops. Olufemi (2008) in a research work titled "Road and urban storm water drainage network integration in Addis Ababa" asserted that urbanization along with its impermeable structures is the major cause of flooding in urban areas.

It is estimated that required drainage channel is short by about 61.78%; and the existing ones are only about 30% maintained, (Amaize, 2011). There is nowhere estimated shortfall in the drainage channels is less than 50% except at Abuja (27%) and Calabar (48%). It is as high as 78% and 76% at Onitsha and Jalingo respectively (Aderogba, 2012). Adeleye and Rustum (2011). An increase of 53.3% in drainage area was obtained in this study. Nwafor (2006) identified 12 causes of urban flooding; these include surcharges in water level due to natural or man – made construction on flood path, sudden dam failure, inappropriate land use, mudflow, inadequate drainage capacity to cope with urbanization, excess encroachment in flood ways, ice jam, rapid snow fall, deforestation of catchment basins, reclamation, construction sites and solid waste. Odemerho (1993) also identified three factors accentuating flood problems in Benin City, Nigeria namely: land and physical development problems, gaps in basic hydrological data, design and implementation problems and cultural factors.

Ochere and Okeke (2012) assess the social impacts and people's perception of flooding events in Makurdi town which has almost become a yearly occurrence. The results of analyses show that floods in Makurdi occur mostly at the event of rainfall intensity and amount and especially at the peak of rainy season (August/September). The study further revealed that factors other than rainfall that substantially influenced flooding in the study area are: Lack of and poor drainage networks, dumping of wastes/refuse in drainage and water channels, topographic characteristics, overflowing of river banks, low infiltration due to high water table and degree of built up areas leading to increased runoffs, and climate change. In similar study elsewhere, Oreola (2003) revealed that high intensity of rainfall, unturned road, dumping of refuse on drainage channels, poor construction of drainage channels and poor town planning practices are the main causes of urban flood problems in the study area in Ado-Ekiti town.

Ladan (2007) reported the incidence of floods due to rapid urbanization in Katsina metropolis. In his study, it was observed that there were inadequate drainages to drain storm water. The result is that the existing drainages become overloaded leading to flooding. Jimoh (2008) assessed drainage problems in the tropical environment of Ilorin. The results of the finding include: the dimensions of drainage channels are adequate to permit free flow of water bodies given a good culture of drainage system maintenance, various types of waste materials but in different proportions have been found to be blocking the drainage channels, the problems of drainage channels ranges from the occurrence of street flooding to environmental deterioration and the splashing of water on other road users. And he concluded that an obvious method for managing drainage channels is the adoption of environmental education with emphasis on the technique for drainage channel management. In a study of drainage systems and urban sustainability in Calabar, Eze (2008) concluded that flooding was observed to be the principal consequence of poor drainage systems.

Within this framework, developing a drainage infrastructure for Isale Koko bears important environmental, economic, social implications crucial for developments and for individuals, especially the residents of the area, who thus far have had to endure the devastating and catastrophic effects of floods on their lives, properties and businesses.

5 Conclusion and Recommendations

Design of drainage infrastructure of Isale Koko, a residential area of Ilorin city was carried out. During appraisal it was discovered that current drainage network in Isale Koko has an estimated area of about 0.44m². The rainfall intensity of the area and discharge flowing into the area were discovered to be 98.46mm/hr and 48.46m³/s respectively. The Isale Koko drainage was divided into three sections giving discharges of 0.55m³/s, 1.11m³/s and 0.55m³/s. With these values of flow, analysis was done to obtain dimensions for new drainages both of rectangular and trapezoidal cross section employing the best hydraulic section method. The dimensions for the rectangular channel were found to be 1.16m×0.812m while that of trapezoidal channel was 0.72m×0.87m with a top width of 1.43m giving areas of 0.67m² and 0.67m² respectively. A comparative analysis that showed an increase in drainage area of 53.3% between pre-existing drainage and the newly designed drainage indicated the inadequacy of the current drainage system of the area.

It is therefore recommended that the current drainage system be replaced by a new one that would sufficiently and effectively manage its storm water. Furthermore to enhance sustainability, all future drainage constructions and other flood mitigating infrastructures should be based on accurate and meticulously gathered data and a body of professionals should be sanctioned with the responsibility of overseeing, managing, evaluating, monitoring and maintenance of the city's drainage system that would ensure that the occurrence of floods within the city is brought to minimum and when they do occur there is an already existent capacity to manage them.

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