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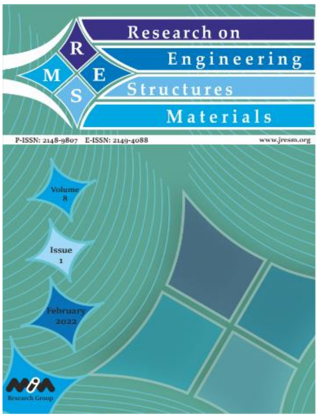

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Technical Note

Economizing the road drainage construction's cost using standard design, offsetting and setting out method: a case study of Ogbomoso – Oko – Osogbo Road, Nigeria

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Abstract

Construction of good roads for the citizens is one of the major duties of the government of a nation. In some nations of the world today, especially some developing nations, many of the federal roads constructed were not performing up to their designed expectations, thus, causing formation of potholes, road surfaces cracking, swaying of road surfaces, road accidents and bad road-drainage structure. The poor drainage system contributed highly to these road defects. Hence, this article provides the standard design and setting out measures for drainage's construction, and for the reduction in its construction cost. In the experiment, the theodolite device was set at an intersectional point (I.P) from chain-ages 8 + 250 to 8 + 417 of Ogbomoso – Oko -Osogbo road. At each I.P, poles were bisected within I.P to I.P1 and I.P to I.P2.The excavated trenches were marked out with pegs for drainage construction. At the bisection of pole 6 and pole B, the excavated depths of the marked areas were increased by 42.3% and 31.4% than the areas with the mean excavation depths compared with other points. Thus, the costs of drainage construction at those points were increased by $2,175.58 and $1,277.32 respectively. This resulted into inflation in the costs of drainage construction at those areas. This construction cost increment was controlled by effective taken off, accurate quantification of project works and standard project's cost estimation. It was concluded that accurate design calculations, good drainage's setting out and project's cost estimation will prevent the construction engineers from run into lost or have excessive spending during the construction of drainage system.

1. Introduction

The duty of a federal government in a nation is to provide her citizens with the best infrastructures, especially, good roads. Many of the roads constructed by the federal government of some developing nations were not performing up to their designed expectations. Thus, causing excessive spends on roads' maintenance. Most of the road faults developed was associated to the poor design and construction of the road drainage structures by incompetent engineers. Most of these quack engineers were not sound in the knowledge of structural design. Some of them were using ideals to design without deeply evaluate the structural perspective of the design and its loading implication. To design structures perfectly, the structural design engineers should have the sound knowledge of British Standard (B.S) code of structural design (like BS 8110: Part1-1997 [1]) and its usage. Also, a drainage design engineer must have the sound knowledge of road design specifications (such as Roads and Bridges specifications 1994 [2]). However, several roads failures developed these days were emanating from poor design (calculations) and construction of road structures, thus, causing a lot of harms to the society and increase the cost of roads maintenance. In the road system, the road drainage

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structure is performing the best roles of maintaining the road stability. According to civil engineering home [3], drainage is defined as the channel of removing water and intercepts from, under and over a specific area of high flow of water.

The problem of covering the road surface with water is the basic roots of ruts and potholes formation in highway system, resulting in long weakening of the road surface. Having experienced road surface's weakening, the load dispersion and bearing capacities of its sub-grade soil will be reducing and become weak. With this developed weakness in the soil, the road sub-grade will be deviated from supporting the road pavement during the road traffic loads (Mugdha [4]). The drainage system is used in highway to evacuate the excess water from the road sub-grade and surface. One of the commonly used road drainage systems is concrete line drain. Concrete line-drain is defined as a straight concrete channel from a conditioning area of water, through which the wash-water and recycle wastes were drained [5]. There are many drainage systems that were commonly used in our societies. For instant, sub-surface, surface, downspout / gutters and slope drainage systems were commonly used in the residential and highway for easy runoff of waste water. The sub-surface drains were normally placed below the soil's top layer to evacuate the runoff water. The surface drainage is usually made inform of ditch for easily evacuation of water. A slope drainage system is commonly constructed for easy flow of water downwardly from a structure through pipe in a suitable slope. The downspout drainage is a drainage system used to collect water from gutters and divert it to the ground [6-7]. It was recorded that, the surface drainage, cross drainage and sub-surface drainage systems were the most suitable drainage systems for the perfect evacuation of water from the highway surface for its durability (Mugdha [4]). As it was known, a professional engineer must be sound in the knowledge of accurate drainage setting out, marking out of straight channels for line-drain construction and determination of accurate locations for offsetting of points to achieve perfect design of concrete drain. Also, the site engineers must have the skill of accurate drainage setting out, standard knowledge of construction, and skill to minimize the cost of construction to achieve better construction of drainage structure.

The design of concrete line drain requires rigorous calculations so as to perfectly determine the loading capacity of the drainage against the forceful water runoff. The quantity surveyors, structural engineers and contractors have to apply the knowledge of Mathematics to determine the weight of the loads from runoff water that a concrete line drain will bear in order to have quality construction of its structure. Mostly, the volumes of the drainage system constructed were determined using the product of its dimensions (Length, breadth and thickness), its quantity unit and cost of each. From the calculations, the costs of drainage construction were determined. In this study, the design of concrete line drain covers: calculating the deflection angle of bisecting points at each location of concrete drain construction from chain-age 8 + 250 to 8 + 417 of 75km road that link Ogbomoso to Oko and Osogbo. It is also covered the determination of drainage's offsetting point, calculating the radius of the road, and determination of cumulative and additional deflection angle for smooth alignment and better offsetting of points.

Retaining of water on the road surface is one of the great flaws caused on the road structural system. The construction of standard drainage structures will help in controlling this defect. As investigated by scholars, poor construction of the road – drainage structures have caused a lot of destruction and deprivation to highways structures than when the constructional part of the road holds loose water. The quality of a water channel is an essential criterion that influences the performance of a constructed road. The construction of inferior water channels on highways had caused a lot of expensive repairs of the destructed parts without fulfilling the expected service lifetime. The deterioration in the properties of road surface materials had also caused the abnormal absorption of water into the road layers. This has caused a lot of untimely failure and development of un-necessary stresses within the road pavement [8]. As recorded by Peter [9], the majority of road drainage system constructed using conventional methods were uneconomical and prone to loss making. Take for instance, the horizontal drainage system is usually constructed in an area where the depth of the desired dewatering is greater or distance from a slope of its flow. The cost of its' trench excavation (blanket drain) and its placement at those points is very high. It is unrealistic and uneconomical. Meanwhile, the method used in this study is so economical and realistic. With accurate measurement in this study, the limit of depth of reinforced concrete drains along with the mean depth would have been determined as early as possible to know how the excess could be handled. The use of accurate measurement and offsetting of points at those points of horizontal drain's construction (through the use of modern equipment) will go in long way in reducing the loss that occurs as a result of excess depths measurement on site. The cost of constructing a drainage system using surface and subsurface methods that were being applied by the previous scholars were very high, because, most of the construction engineers were focusing on the volume of drains to construct but not on cost implication of the construction even if the depth is beyond expectation [10]. From the measurement, the costs of drain's volume were being reduced using the method of this study. One of the disadvantages of the method use in this study is that, its implementation cannot be done without making use of bisecting and measuring instruments.

According to Jitendra et al. [11], an easy way of measuring the drainage performance should be developed to determine the structural – quality of the road drainage and its impact on the rigid performance of the road pavement against the deterioration and coarseness. This observation is very important for the prevention of expensive spending on maintaining the road surface. These were the methods adopted by the authors to conserve the India's great road network.

In the investigation carried out by Magdi [12] on the analysis of highway drainage problems in Khartoum State of Sudan. In the analysis, many roads were selected and observed critically for more improvement. The outcome revealed that, several road systems in Khartoum State were faulty, resulting in the destruction of some road pavements in the state at their early stage of service. Moreover, poor drainages in Khartoum state had developed unhygienic environment for the people of the State. As a result of the poor drainage structures, the flood water was forced to the road surface from the sides of the road. This led to the early destruction of highway pavements in the State. Some of the discovered factors causing poor drainage system in Khartoum are inaccurate highway geometrical design, inadequate drainage structures for perfect flow of water, poor construction of drainage structures, and poor maintenance of both drainage and road pavement. After the problems associated to the drainage system were discovered, the provisions of adequate connections between highway and drainage network structures were suggested. Provisions were made to preserve and maintain this connection. With these provisions, the performing quality of the highway drainages was improved by reconstructing the failed parts of the drainage structures and provided proper maintenance of both drainage and pavement structures. Furthermore, it was suggested that, there should be yearly budget allocation for the maintenance of both highway drainages and pavements. Also, a standard software should be developed that can perfectly be used for planning, analyses and design of highway drainage structures for the sustainability of both drainage structures and highway pavements in the urban cities of Khartoum State.

In the investigation conducted by Yuki et al. [13], it was stated that, the construction of domestic drainage system requires the use of maximum water discharging capacity for its construction through the standard setting out of the drain. With the use of this parameter, it will prevent the effect of water seal losses and pressure fluctuation in the drainage system.

Dieter [14] reported that, the road water drainage systems were normally constructed to acquire some set objectives. Besides, there should be proper consideration of some technical standard, economizing of construction cost, life safety, and public safety to build a standard drain structure with high level of technical integrity. To achieve quality design, the structural design engineers have to consider some basic rules of design, knowledge of flood and erosion control before embarking on drainage structural design. Furthermore, Dieter [14] outlined that, many drainage structures were built with standard materials for perfect drainage operation in Alberta some years ago. These drainage structures were accurately designed to withstand the force of water overflow in the drainage systems. The technical uprightness of the drainage structure was maintained by retaining the prominence of the drainage structural design procedures. Also, according to Guest post [15], one of the engineering tools required for the construction of stable drainage system is land investigation. This investigation is very important in determining the slope and topography of the land for easy drain of water. Likewise, the average of annual rainfall of the area where the drainage is to be constructed should be know to prevent the excessive flow beyond the capacity of the constructed drainage system.

These scholars have done some good jobs, but, none of them was able to combine the work of designing and construction of road drainage with their cost implications. Thus, this study aimed at providing the standard setting out method for the road-drainage construction. With this method, the fixing out of local points for accurate construction will be easier. Also, it will help in constructing a standard concrete line-drain from the road curve deflection angle. Having acquired these inputs, the cost of drainage construction will be more economized. Likewise, there will also be a proper stability of road pavements for easy draining of water from the road surface, especially at chain-ages 8 + 250 to 8 + 417 of Ogbomoso – Oko -Osogbo road, Nigeria. The Ogbomoso – Oko – Osogbo road is a federal government road situated around South West of Nigeria. The road is about 75 kilometres in length. It linked the two States of the nation (Nigeria) together (Oyo and Osun States). Figure 1 shows the image of a trench drain and a concrete line-drain.

(a)

(b)

Fig. 1 Trench drains (a); Concrete line-drain (b)

2. Materials and Methods

2.1. Materials

The devices used for the accurate construction of concrete line-drain and its fixing out from the road's deflection curve angle are presented in the following subsections.

2.1.1 Theodolite, Levelling Instrument and Tripod Stand

A theodolite is defined as an accurate discernible device usually used for the computation of angle in between the selected obvious horizontal and perpendicular points to provide the angular declamation [16]. A theodolite instrument consists of a telescope that can be rotated to all sides of horizontal and perpendicular axes. It was used on site for the measurement of the road curve deflection angles in-between the local points of the road. A level device is a visual instrument used to set up or confirm points in the same straight horizontal in an operation known as leveling which is used along with survey staff to stare the comparative heights alignments [17]. Tripod Stand is an instrument upon which the theodolite or leveling device is mounted. It consists of three legs for stability and for maintenance of levels during the measurement of angles and alignments. It is usually used for the erection of the instruments like theodolite and level, for easy measurement of deflection angles and maintenance of standard levels on site.

2.1.2 Field book, Pen and Pencil

A field book is an hard material (book) used for recording technical measurements, rough sketches and keeping the account of all the site measurements. A pen is a writing material used for the documentation of field records, accounts and some important information needed for easy site work while a pencil is a material purposely used for sketching and drawing of site images and details. All the structural drawings were initially sketched on site using pencils and later documented adequately in the design office.

2.1.3 Cutlass, Measuring Tape, Hammer, Pegs and Ranging Poles

A cutlass is a sharp equipment used for the clearing of bushes around the area where the specific construction will take place. It was used to clear bushes around the area where the construction of concrete line-drain was to take place then on site. This was done in order to have the clear measurement of the deflection angles on site. A measuring tape is leather or clothing calibrated material usually used for the measurement of distances in between the horizontal and perpendicular points. Hammer was used on site to hit the pegs and poles firmly to the ground during the measurement of deflection angles and drain's setting out. Pegs were used for the fixing out and offsetting distances in the excavation of construction areas of drainages and to fix out trenches for buildings construction. Ranging poles were used for the construction and transferring of the straight alignment from the theodolite's intersection point with a specified deflection angle to the point of constructing and offsetting the concrete line-drain at the close and long distance of projections.

2.2. Methodology

2.2.1 The Previous Methods of Designing the Peak Flow of a Drainage System

Latif et al. [18] stated that, the peak of a drainage flow system can be perfectly determined using any of the following methods, that is, soil conservation service method, curve number method, cook's method, and rational formulation method. The rational formulation method is commonly use in the tropical areas or where the water runoff requires large culverts and channels. With rational formulation method, the peak flow of a drainage system can be calculated using $qp = (CIA)/360$ where C is the coefficient of runoff which is dimensionless; I is the intensity of rainfall; A is catchment area (ha); and qp is drainage water peak flow. The method of this study shows more effectiveness in discharging the flow from the drainage system than the above-named methods.

2.2.2 Construction of Concrete Line Drain (New Method)

2.2.2.1 Construction of Concrete Line Drain (New Method)

On site, when the drain was under construction, the theodolite instrument was removed from its box and fixed on the tripod stand. The three legs of the tripod stand were tilted for the successful support of the instrument and firmly erections of the pods. The theodolite device was tightly fixed with the tripod stand at the right location. The theodolite instrument together with the tripod stands was set at the centre of the road under - construction at an intersection point (I.P). The two other local intersection points (I.P) 1 and 2 were located from original I.P. I.P1 and I.P2 were located at extreme edges to each other, so that, their tangent line (T.L) will meet at point I.P. As the fixed theodolite with the tripod stands was placed at the intersection point (I.P), at that I.P, the theodolite telescope was turned to bisect I.P1 and I.P2 after the instrument was set to angle zero (0.0), respectively. At the time of bisecting I.P2 after the bisection of I.P1 from I.P, the deflection angle (Δ) was recorded at both of I.P1 and I.P2 on the instrument as $22^{0}39^{1}09^{11}$ each at chain-ages 8 + 250 to 8 + 417 of the road. The half of each deflection angle (Δ) was calculated to be $11^{0}19^{1}40^{11}$. Then, the external distance (E.D) from I.P to the edge of the road's shoulder or road itself was measured to be 7m. The radius of the road deflection curve (R) was calculated using the Equation (1).

$$\text{Radius of road deflection curve (R)} = \frac{E.DxCos\left(\frac{\Delta}{2}\right)}{1 - Cos\left(\frac{\Delta}{2}\right)} \tag{1}$$

The calculated radius was used to calculate for the tangent length (T.L), Chord Length (C.L) and to determine the measurable interval for alignment location for continuous offsetting of straight line during the drainage construction using Equations (2) to (4).

$$\text{The Interval for alignment off} - \text{setting (I)} = \frac{\text{(Chord Length (C.L))}}{\text{(Number of points at which pegs will be fixed)}} \tag{2}$$

$$\text{Chord Length (C.L)} = \frac{2\Pi R\Delta}{360} \tag{3}$$

$$\text{Tangent Length(T.L)} = RxTan\left(\frac{\Delta}{2}\right) \tag{4}$$

Then, the angles at each specified interval were calculated to get the cumulative additional angles until the point of acquiring the initial deflection angle (Δ) using Equation 5.

$$\text{Additional Angle (A.A)} = \frac{\Delta xInterval}{C.L} \tag{5}$$

The measuring tape was used to measure the interval of offsetting pegs from E.D or I.P to points $I.P_1$ and $I.P_2$. The calculated interval measured was 23.73m. The pegs offsetting was made within the points of I.P and $I.P_1$; and point of I.P to $I.P_2$ until $I.P_1$ and $I.P_2$ meet. At the point of each offsetting, pegs were hammered down at exact 23.73m interval. Adjacent to the pegs hammered down at 23.73m interval, the measuring tape was used to offset another new point with the peg directly opposite to the initial peg at the interval of 1.6 m, to form the alignment of the length for the excavation of trenches for the construction of concrete line-drain as shown in Fig.2.

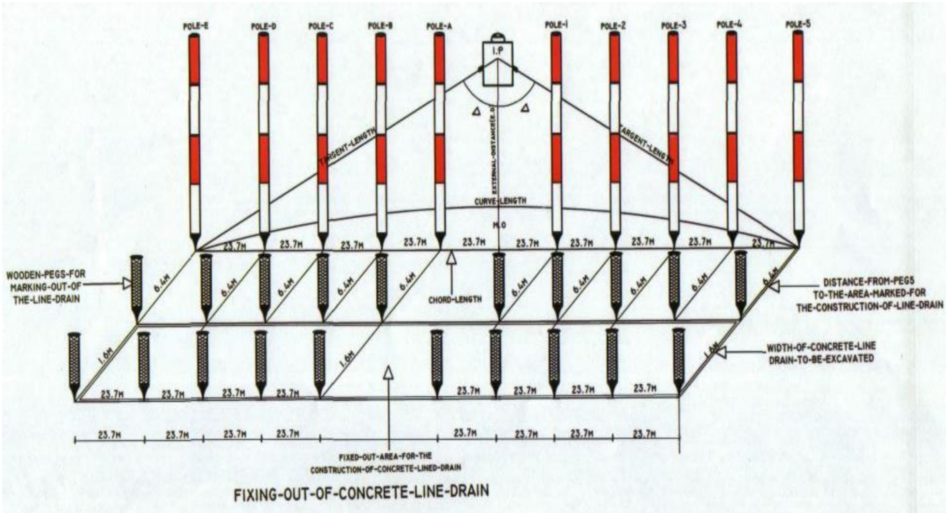

Fig. 2The fixing out of concrete line-drain from the deflection angles

2.3. Determination of Excavation Depth of Concrete Line-Drain's Trenches for Easy Construction

The highest central point of the road under - construction is the best local point for the determination of the concrete line-drain's height for its accurate construction. As conducted on site, the calibrated survey staff was placed at the centre of the road and the readings were taken and recorded accordingly. After the staff readings, the depths of the filling and levelling required to fill the bases of the excavated trenches for the construction of concrete line drain were determined and added to the staff readings. Then, the depths of the excavated trenches of the concrete line drain together with that of filling and levelling calculated were transferred to the excavated areas of the drain to determine the exact depths of the excavated areas. In a case where the depths were not reached, the iron pegs were hammered to the ground until the depths were ascertained to know the level at which the excavation of the trenches would reach. This was done by measured the half of the breadth of an excavated trench, that is 0.8m, placing an iron peg at the point, and hammered it down. Then, the calibrated staff was placed at the top of the peg and a reading was taking. The iron peg was adjusted until when the value of the staff reading at central point of the road was successfully determined to be the exact value transferred from the excavated area. After the accurate excavation of trenches, the bases of the excavated trenches were levelled with lateritic soil material to the depth of 0.15m. Then, the lateritic soil was well compacted and its top was reinforced with concrete. The concrete aggregates mix ratio used was 1:3:6 which signified 1 head pan of cement, 3 head pans of sand and 6 head pans of granite. Then, some U-shape steel bars were placed on top of the cast base of the excavated trenches. Then, the steel bars were cast together with the base concrete using the concrete mix proportion of 1:2:4. Immediately after the base reinforcement, the casting of concrete wall of the drain was followed using the same 1:2:4 mix ratio. The qualities of the concrete cast were determined using slump and cube testing instruments.

2.4. The Output of Deflection Analysis in Summary

The outputs of the above analysis were shown in Tables 1 and 2. The deflection angle used was 2203912011 for each of the I.P to I.P1 and I.P to I.P2. The external distance

(E.D) used was 7m, and the height of the filling and levelling of the excavated trench used was 400 mm. The Table1 presents the summary of the allocation of deflection angle ($22^{0}39^{1}20^{11}$) at I.P to I.P1 while the Table2 presents the summary of the allocation of deflection angle ($22^{0}39^{1}20^{11}$) at I.P to I.P2.

Table 1. The allocation of $22^{0}39^{1}20^{11}$ at intersecting point 1 (I.P$_1$) from I.P.

Poles No.	Deflection angle (Δ) in degree	Additional angle in degree	Cumulative of deflection angles (degree)	Bisecting interval (m)	Staff reading at the centre of the roads (m)
0	$22^{0}39^{1}20^{11}$	$0^{0}00^{1}00^{11}$	$0^{0}00^{1}00^{11}$	23.73	0.000
1	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$3^{0}46^{1}35^{11}$	23.73	1.226
2	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$7^{0}33^{1}10^{11}$	23.73	1.217
3	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$11^{0}19^{1}45^{11}$	23.73	1.625
4	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$15^{0}06^{1}20^{11}$	23.73	1.942
5	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$18^{0}52^{1}55^{11}$	23.73	1.543
6	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$22^{0}39^{1}30^{11}$	23.73	2.671

Table 1. (Con.) The allocation of $22^{0}39^{1}20^{11}$ at intersecting point 1 (I.P$_1$) from I.P.

Poles No.	Depth to excavate (m)	Mean of excavation depths (m)
0	0.000	1.803
1	1.626	1.803
2	1.617	1.803
3	2.025	1.803
4	2.342	1.803
5	1.943	1.803
6	3.071	1.803

Table 2. The allocation of $22^{0}39120^{11}$ at intersecting point 2 (I.P2) from I.P.

Poles No.	Deflection angle (Δ) in degree	Additional angle in degree	Cumulative of deflection angles (degree)	Bisecting interval (m)	Staff reading at the centre of the roads (m)
0	$22^{0}39^{1}20^{11}$	$0^{0}00^{1}00^{11}$	$0^{0}00^{1}00^{11}$	23.73	0.000
A	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$3^{0}46^{1}35^{11}$	23.73	2.008
B	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$7^{0}33^{1}10^{11}$	23.73	2.222
C	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$11^{0}19^{1}45^{11}$	23.73	1.419
D	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$15^{0}06^{1}20^{11}$	23.73	1.427
E	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$18^{0}52^{1}55^{11}$	23.73	1.331
F	$22^{0}39^{1}20^{11}$	$3^{0}46^{1}35^{11}$	$22^{0}39^{1}30^{11}$	23.73	1.792

Table 2. (Con.) The allocation of $22^{0}39^{1}20^{11}$ at intersecting point 2 (I.P2) from I.P.

Poles No.	Depth to excavate (m)	Mean of excavation depths (m)
0	0.000	1.800
A	2.408	1.800
B	2.622	1.800
C	1.819	1.800
D	1.827	1.800
E	1.731	1.800
F	2.192	1.800

3. Results and Discussions

3.1. Line Drains Excavation Depths and the Depths Differences from I.P to I.P.1

The results of the actual depths and mean depths of the excavated line-drain trenches from I.P to I.P1 at chain-age 8 + 250 to chain-age 8 + 417 are shown in Fig. 3.

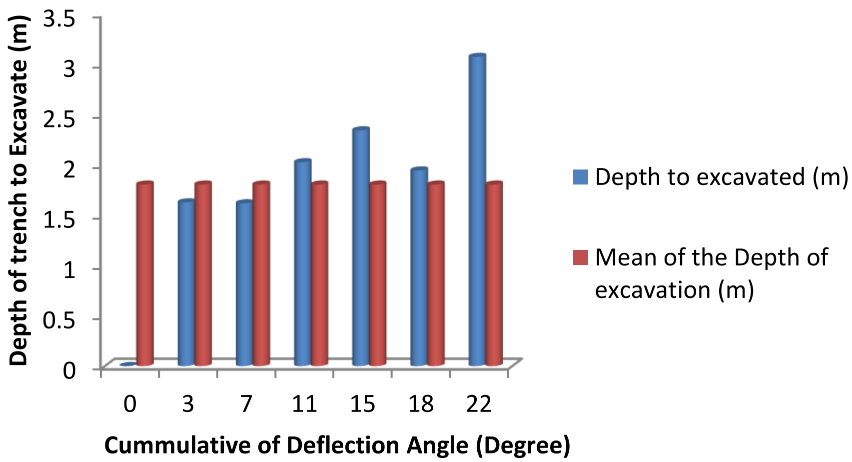

Fig. 3 The actual and mean depth of concrete line-drain's excavating trenches from I.P to I.P1.

The mean depths of the excavated trenches of concrete line-drain together with the depth values transferred from the centre of the road to the excavated areas were presented in figure 2. Their implications on the cost of line-drain's construction were observed also. As shown in Fig. 3, the mean of the road's depth transferred from the centre of the road to the excavated area were indicated by red bars. While the depths of the trenches of concrete line drains to be excavated were represented by blue bars. As indicated with the bars, it was discovered that, the depths of the areas to be excavated for the construction of the concrete line drain was deeper than the required depths. With these excess depths, more expenses were required to achieve the perfect drain construction. Thus, this inflates the cost of drainage construction. Considering the bisection of Poles 1and 2, the deflection angle recorded was $3^{0}46^{1}35^{11}$ at each point. From the critical observation of their excavation depths, the average (mean) depth of poles1 & 2 at the excavated areas were more than that of the actual depths at those locations by 9.8%. This implied that, the trenches excavated at those two locations (Poles 1&2) need adjustment to prevent excessive spending during the construction of the drain. Up to 9.8% of these excavated areas should be corrected as quickly as possible. To correct the 9.8% of point's difference, additional excavation depth is required. This will increase the workers' wages by 9.8% and also increase the cost of drain construction as well. Likewise, the actual excavation depth observed at the point of bisecting pole 3 with $7^{0}33^{1}10^{11}$ deflection angle is more than that of the area with the average drain's depth by 10.3%. With this depth difference, up to 10.3% of sand filling and concrete is required to achieve the desired depth standard good for concrete structural stability in that location. As it has been known that, the mean depth is the required depth of the excavation, thus, the additional 10.3% of base sand filling and concrete reinforcement will increase the cost of both construction materials and labours' wages respectively. Also, the excavation depths of the highlighted areas for line-drain construction at the point of bisecting pole 4 were by 23% more than that of areas with mean depths. At those points, more lateritic soils for base filling and more concrete reinforcement were needed. This inflates the cost of drainage construction (on materials and labours) at those areas by 23%. With the deflection angle of $18^{0}52^{1}55^{11}$, the different between actual and mean depths of the line-drain excavated areas at the point of bisecting pole 5 was so minimal. These areas require less fillings and less additional reinforcement, just about 7.2% is needed. With the depth increment of about 7.2%, the cost of line drain construction will also increase, but the increase will be minimal (just 7.2%). The trenches excavated depths differences of the areas observed were too wide at the point of bisecting pole 6 with $22^{0}39^{1}30^{11}$ deflection angle. As recorded, the depths of the areas highlight for the drains' trenches excavation were more than that of the mean excavation depths of the same areas by 42.3%. This is implied that, the volume of additional materials (base soil filling and concrete) needed for the reinforcement at those areas is about 42.3%. The additional cost of construction at that point of excavated areas required almost half of the total cost of construction (42.3%). These areas need special attention to be able to eradicate the extra-expenses completely. Considering the excavating depth results, there is inflation in the construction cost of concrete line-drain at each area of bisecting poles and this is becoming un-encouraging. These excessive spending were fixed during the drainage's design stage using accurate calculations, proper taken off and standard cost estimations. From the observation of the above results, it was discovered that, the depth results of poles bisection at areas 2, 3 and 6 require proper and accurate cost estimations. Following the above methods, there will be a reduction in the excessive cost of drainage construction. Also, the site engineers will be prevented from running into unwanted loss. Application of this study's method to Khartoum's drainage problems will really improve its poor performance of drainage system as stated by Magdi [12] through the use of accurate highway geometrical design method. Also, the application of the method will go in long way in guiding the nations in the globe to maintain the integrity and standard of the road drainage structures. The technical standard of the road drainage will be retained and its construction cost will be minimized if the method of this study is applied to solve the problems stated by Dieter [14] as stated in his study. Most of the roads in the developing countries can regain their stability and integrity back if the method used in this study can be adopted to identify some excess depths in their drainage constructions that lead to excessive spending on site. With this, the problem of extra-cost of drainage construction will be totally eradicated.

3.2. Line Drains Excavation Depths and the Depths Differences from I.P to I.P.2

Fig. 4 shows the results of the actual and mean depths of the excavated areas for the construction of concrete line-drain at I.P2 from I.P as transferred from the center of the road under construction at chain-age 8 + 250 to 8 + 417

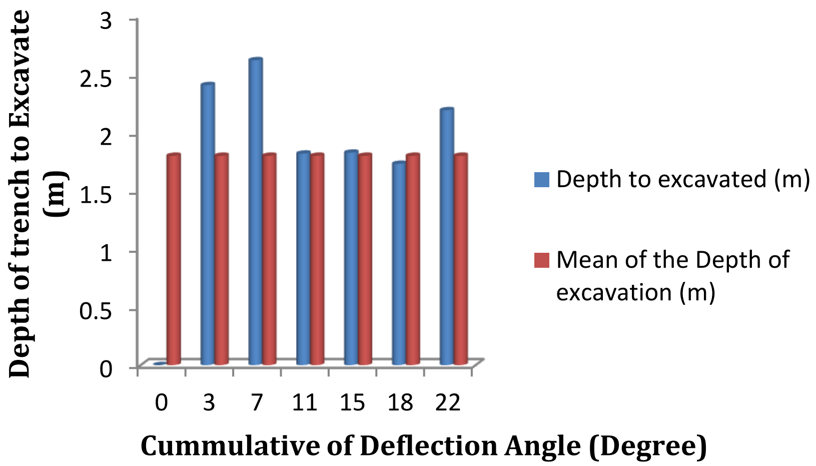

Fig. 4The actual and mean depths of the excavated trenches of concrete line – drain from I.P to I.P2.

The differences between the mean depths of the excavated areas for the construction of the concrete line-drain and that of the actual depths of the excavated areas at the point of bisecting pole A (with deflection angle of $3^{0}46^{1}35^{11}$) was 25.2%. This depths increment inflated the cost of line-drain construction at point A's area by 25.2%. At the bisection of pole at point B, the actual and mean depths of the area were deferred by 31.4%. At the stage of this project cost estimation, the 31.4% depths difference was eradicated by using accurate offsetting and costing of the drain's excavated area. Likewise, the actual depths observed at the point of bisecting poles C, D and E were almost equal to mean depths of the areas for line-drain construction. The differences here are minimal compared with that of areas of bisecting Poles A and B. No additional cost of construction was required around C, D and E areas, and if required, it will not be more than 1.5% (as shown around pole E). 1.5% increment is so small compared to that of areas around poles A, B and F. Furthermore, the increment in the cost of concrete line drain construction at pole F area was about 17.9%. This implied that, the actual depth of the area around pole F was by 17.9% more than the mean depth of the area. In other word, the cost of concrete line drain construction at that point is influenced by 17.9%. Hence, 17.9% excess cost of drainage construction is required for the construction of concrete line drain at point of bisecting pole F. With the knowledge of accurate cost estimation in this study, site engineers can construct good drainage structures without running into losses. Also, this study will guide the design engineers to acquire the sound knowledge of line drain design, construction and accurate use of the code of structural design (BS 8110:1997-part 1). In addition, this study will really help the design and site engineers to construct stable concrete line-drains for easy run-off of water from the surface of the road to the drainage systems, cancelling the major problems of highway drainage structures stated by Owuama et al [19]. The expensive spending on concrete drainages' deteriorations mentioned by Jitendra et al [11] in their studies can be fixed, if the method of drainage design, construction and cost estimation used in this study is adopted for the construction of their drainage systems.

3.3. Methodology

3.3.1 Estimated Cost Implication 1

Table 3 shows the actual cost for the construction of concrete line drain at the excavated areas from I.P to I.P1 while the Table 4 shows the mean cost of concrete Line drain construction from I.P to I.P 1. The volumes of the concrete drains were calculated from the product of the drain's length (1.6m), its breath (staff reading value) and the thickness (staff reading value) of the base of the line-drain. This estimated cost covered the line-drain bases' construction only, walls are not included. From the estimation made on construction cost, the estimated cost of concrete line drain construction at pole 6 area (see table 3) was more than that of the area with mean excavated depth at the same location by $ 2,175.58 (see table 4). The cost difference is about 65.5% of the actual cost. The 65.5% excess in the cost of drainage construction can cause the structural engineers, contractors and site engineers to run into high unexpected debts during construction stage. The method of estimation and costing of this study will help the site engineers to fix out any excessive costs at the initial stage of their projection cost estimation.

Table 3. The actual cost of concrete line-drain's construction from I.P to I.P1 in US Dollars

Pole No.	Cumulative of deflection angles (degree)	Depth to excavate (Thickness) (m)	Length (m)	Breadth (m)	Volume of concrete for the actual excavated areas (m^3)
0	$0^{0}00^{1}00^{11}$	0.000	1.600	0.000	0.000
1	$3^{0}46^{1}35^{11}$	1.626	1.600	1.626	4.230
2	$7^{0}33^{1}10^{11}$	1.617	1.600	1.617	4.184
3	$11^{0}19^{1}45^{11}$	2.025	1.600	2.025	6.561
4	$15^{0}06^{1}20^{11}$	2.342	1.600	2.342	8.776
5	$18^{0}52^{1}55^{11}$	1.943	1.600	1.943	6.040
6	$22^{0}39^{1}30^{11}$	3.071	1.600	3.071	15.090

Table 3. (Cont.) The allocation of $22^{0}39^{1}20^{11}$ at intersecting point 1 ($I.P_1$) from I.P.

Poles No.	Cost per unit volume of concrete (m^3) in USD ($)	Actual cost of concrete construction at the drain excavated areas ($)
0	220.00	0.00
1	220.00	936.60
2	220.00	920.48
3	220.00	1,443.42
4	220.00	1,930.72
5	220.00	1,328.80
6	220.00	3,319.80
		$ 9,879.82

Table 4. The mean cost of concrete line-drain's construction from I.P to I.P1 in US Dollars

Pole No.	Cumulative of deflection angles (degree)	Depth to excavate (Thickness) (m)	Length (m)	Breadth (m)	Volume of concrete for the actual excavated areas (m^3)
0	$0^{0}00^{1}00^{11}$	0.000	1.600	1.803	0.000
1	$3^{0}46^{1}35^{11}$	1.803	1.600	1.803	5.201
2	$7^{0}33^{1}10^{11}$	1.803	1.600	1.803	5.201
3	$11^{0}19^{1}45^{11}$	1.803	1.600	1.803	5.201
4	$15^{0}06^{1}20^{11}$	1.803	1.600	1.803	5.201
5	$18^{0}52^{1}55^{11}$	1.803	1.600	1.803	5.201
6	$22^{0}39^{1}30^{11}$	1.803	1.600	1.803	5.201

Table 4. (Cont.) The mean cost of concrete line-drain's construction from I.P to I.P1 in US Dollars

Poles No.	Cost per unit volume of concrete (m^3) in USD ($)	Actual cost of concrete construction at the drain excavated areas ($)
0	220.00	0.00
1	220.00	1,144.22
2	220.00	1,144.22
3	220.00	1,144.22
4	220.00	1,144.22
5	220.00	1,144.22
6	220.00	1,144.22
		$ 6,865.32

3.3.2 Estimated Cost Implication 2

Table 5 shows the actual cost of constructing concrete line drain at the excavated areas from I.P to I.P2 while the Table 6 shows the mean of cost of concrete line-drain's construction from I.P to I.P 2. From the estimation made, the cost of concrete construction at pole B (see table 5) is more than that of the mean one at the same location by $ 1,277.32 (see Table 6) which is about 52.8%. This implied that, the cost of line-drain construction was increased by 52.8%. Almost half of the construction cost at the bisection of pole at point B will be added as excessive cost of drainage construction compared to that of other points.

Table 5. The actual cost of concrete line-drain construction in Dollars from I.P to I.P2

Pole No.	Cumulative of deflection angles (degree)	Depth to excavate (Thickness) (m)	Length (m)	Breadth (m)	Volume of concrete for the actual excavated areas (m^3)
0	$0^{0}00^{1}00^{11}$	0.000	1.600	0.000	0.000
A	$3^{0}46^{1}35^{11}$	2.408	1.600	2.408	9.278
B	$7^{0}33^{1}10^{11}$	2.622	1.600	2.622	10.999
C	$11^{0}19^{1}45^{11}$	1.819	1.600	1.819	5.294
D	$15^{0}06^{1}20^{11}$	1.829	1.600	1.829	5.352
E	$18^{0}52^{1}55^{11}$	1.731	1.600	1.731	4.794
F	$22^{0}39^{1}30^{11}$	2.192	1.600	2.192	7.687

Table 5. (Cont.) The actual cost of concrete line-drain construction in Dollars from I.P to I.P2

Poles No.	Cost per unit volume of concrete (m^3) in USD ($)	Actual cost of concrete construction at the drain excavated areas ($)
0	220.00	0.00
A	220.00	2,041.16
B	220.00	2,417.80
C	220.00	1,164.68
D	220.00	1,177.44
E	220.00	1,054.68
F	220.00	1,691.14
		$ 9, 546.90

Table 6. The Mean cost of concrete line-drain construction in Dollars from I.P to I.P2

Pole No.	Cumulative of deflection angles (degree)	Depth to excavate (Thickness) (m)	Length (m)	Breadth (m)	Volume of concrete for the actual excavated areas (m^3)
0	$0^{0}00^{1}00^{11}$	0.000	1.600	1.800	0.000
A	$3^{0}46^{1}35^{11}$	1.800	1.600	1.800	5.184
B	$7^{0}33^{1}10^{11}$	1.800	1.600	1.800	5.184
C	$11^{0}19^{1}45^{11}$	1.800	1.600	1.800	5.184
D	$15^{0}06^{1}20^{11}$	1.800	1.600	1.800	5.184
E	$18^{0}52^{1}55^{11}$	1.800	1.600	1.800	5.184
F	$22^{0}39^{1}30^{11}$	1.800	1.600	1.800	5.184

Table 6. (Cont.) The mean cost of concrete line-drain construction in Dollars from I.P to I.P2

Poles No.	Cost per unit volume of concrete (m^3) in USD ($)	Actual cost of concrete construction at the drain excavated areas ($)
0	220.00	0.00
A	220.00	1,140.48
B	220.00	1,140.48
C	220.00	1,140.48
D	220.00	1,140.48
E	220.00	1,140.48
F	220.00	1,140.48
		$ 6,842.88

4. Contribution to Knowledge

The novelty of this studies on drainage construction is that the mean cost of drainage construction can be determined from the volume of its dimensions. This will eventually reduce the cost of drainages' construction together with its cost differences as shown in Tables 3 to 6. The estimated cost of subsurface drainage construction carried out by Wada et al. [20] was done without showing volume by volume –cost estimations. Their calculations were just on rough estimations made through some assumptions as shown in Table 7. The actual limits that a drainage system under construction could reach were not determined or specified in Wada et al. [20] method used for drainage design and construction. This could lead to the excessive use of materials during the construction of drainage system, thus, increase its construction's cost.

Table 7. Preparation and feasibility cost analysis (Wada et al. [20])

S/N	Unit	Item	Unit cost Nigerian Naira (#)	Quantity	Unit cost Nigerian Naira (#)
		Feasibility Study:			
1	Person days	Time Input	8,000.00	5	40,000.00
		Subtotal feasibility study			
		Field Investigation:			
		Topographic Survey			
2	ha	Area Topography	100,000.00	1	100,000.00
3	km	Alignments	50,000.00	1	50,000.00
		Pre-drainage soil survey:			
4	ha	Area soil survey	20,000.00	1	20,000.00
5	No. of sample	Laboratory analysis	5,000.00	5	25,000.00

Table 7 (Cont.). Preparation and feasibility cost analysis (Wada et al. [20])

S/N	Unit	Item	Unit cost Nigerian Naira (#)	Quantity	Unit cost Nigerian Naira (#)
		Feasibility Study:			
		Subtotal survey			195,000.00
		Design:			
6	ha	Design of subsurface network	200,000.00	1	200,000.00
7	unit	Design of associated network	50,000.00	4	200,000.00
		Subtotal design			400,000.00
		Total pre-construction cost			635,000.00

With cost estimation method shown in Table 7, there could be excessive use of material which could inflate the cost of drainage construction. The actual dimensions of the drainage construction areas were not shown to proof how efficient is the drainage construction cost estimated. In these studies, the actual dimensions of the drainage to be constructed is shown, and the excess material and its cost implication can be quickly identify and corrected to avoid running into debts by constructing engineers and the contractors. One of the dangerous causes of the deteriorations in drainage concrete systems as stated by Jitendra et al [11] might have occurred as a result of poor concrete drainage's structural design, poor offsetting of points and inefficient drainage setting out. The accurate method of offsetting, designing and setting out of concrete line drain used in this study will go in long way in preventing the frequent maintenance of drainage system that might have been emanated from constant deteriorations of concrete drainage system.

5. Conclusions

As discussed in this study, highway drainage structure is one of the most sustainable parts of the road network systems. This study has provided the accurate method of designing and constructing concrete-line drain from the angle of road deflection curve. Also, it has provided the best method of economizing the cost of drainage construction. With the critical observation of the study on concrete line-drain's construction, the accurate setting out of concrete line-drain will be of help in determining the actual cost of its structural construction without running into loss or debts. Also, proper offsetting and setting out of concrete line drain will prevent overspending on the cost of drainage construction. The accurate pegs offsetting and distance measurements is a perfect step of constructing straight line-drains for smooth hydraulic flow in highway system. The application of this method of drainage construction will contribute to the construction of stable drainages and highway pavements in the global drainage system. Also, it is concluded that, a well designed and constructed line-drain will gain more strength to withstand the effect of flood in highway systems. It will provide a smooth channel for easy transportation of runoff water from the road surface. With the above results, it was recommended that, the accurate drainage's points offsetting, the setting out and construction method used in this study should be adopted by site engineers and contractors for the design and construction of drainage structures to prevent them from running into losses.

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