ASSESSMENT OF DRAINAGE STRUCTURES FROM BABALOLA JUNCTION DOWN TO AYEGUN RIVER OF IRARE ESTATE, OYE EKITI, EKITI STATE, NIGERIA

BY

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ABSTRACT

Globally, natural disasters are becoming places lately, and they are the results of climate change due to natural forces. Some of these disasters like floods, earthquakes, landslides and draught happen, resulting in loss of human lives and properties. Flood occurs when two or more acres of dry land or two or more properties are inundated by water or mudflow. In this study, the reconnaissance survey of the study area was carried out. The topographical map of the area contributing runoff to the drainage structures of the study area was identified through desktop analysis. Appropriate formula was used to estimate the discharge and thus, calculate the required cross-section areas of drainage structure and compared to the existing cross-section areas to find out whether they were adequate or not. The structural designs of the new drains was carried out based on the results from the hydraulic analysis using BS 8110 and BS 5400. The hydraulic analysis revealed that the average existing cross-sectional area of the drains is $0.21m^2$ as opposed to the required cross-sectional area of $1.44m^2$. This indicates that the line drains are not adequate to contain surface runoff. Therefore, it is recommended that the existing drains and culverts be demolished and reconstructed. The average cross-sectional areas at sections 1, 2 and 3 of the drains should be redesigned to $2.25m^2$. Concrete grade of $25N/mm^2$ should be used for both culverts and drains. Also, high yield reinforcements of Y16@200mm $^{c}/_{c}$ should be used as main bar and Y12@300mm $^{c}/_{c}$ as distribution bar for culverts. High yield reinforcements of Y16@200mm $^{c}/_{c}$ should be used as main bar and Y10@300mm $^{c}/_{c}$ as distribution bar for line drains.

ACKNOWLEDGEMENT

I will like to express my sincere gratitude to my project supervisor, Dr. Aderinola O.S. for giving me the opportunity to work on this topic. It would never be possible for me to take this project to this level without his innovative ideas and his relentless support and encouragement.

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It will be most ungrateful of me to fail to recognize the financial assistances of my uncle, Mr. Dayo Bobadoye and my lovely aunt Mrs. R.B Ojo for her priceless encouragement.

To my uncle Mr. G.K. Bobadoye, your fatherly love has kept me going. Thank you.

DEDICATION

This project is dedicated to God Almighty, whose grace and faithfulness has been and will never cease. And to my parent, Mrs. Bosede Bobadoye for her motherly love, encouragement, efforts and supports put towards the success of this work. Finally, I dedicated it to everyone who had contributed to the success of this project.

CERTIFICATION

This is to certify that this project entitled "ASSESSMENT OF DRAINAGE STRUCTURES AT IRARE ESTATE, OYE EKITI, EKITI STATE, NIGERIA" by BOBADOYE TUNDE MICHAEL (CVE/13/1056), submitted in partial fulfillment of the requirements for the degree of Bachelor of Engineering (B. ENG.) in CIVIL ENGINEERING of Federal University Oye-Ekiti, during the academic year 2013-2018, is a bonafide record of work carried out under my guidance and supervision.

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CHAPTER ONE

INTRODUCTION

1.1 General Background

In the world over, natural disasters are becoming common place lately. They are a result of sudden change in state of natural elements (e.g. climate change) due to natural forces. Most of the natural disasters are beyond human control and cannot be accurately predicted before their occurrences. When key natural disasters like flood, earthquakes, landslides and drought happen, they result in loss of human lives and properties, and they equally affect the infrastructure, agriculture and environment. The impact of disasters is always difficult and fatal due to its intensity and coverage.

Flood may be defined as a discharge which exceed the channel capacity of a river course and then proceed to inundate the adjacent flood plain. Such high flows are normally caused either by intense or prolonged rainfall (Watson, 1989). In general, a flood is a temporary condition where two or more acres of dry land or two or more properties are inundated by water or mudflow. It is an outflow of an expanse of water that submerge land and properties. The European Union Flood Directive defines flood as a temporary covering by water of land not normally covered by water. In the sense of a flowing water, the word may also be applied to the inflow of the tide. Flooding can be exacerbated by increased amounts of impervious surface or by other natural hazards such as wildfires, which reduce the supply of vegetation that can absorb runoff.

Drainage is one of the measures employed to manage and control flooding. It is an integral part of any road design and construction. Inadequate drainage system will promote flooding, road deterioration and subsequent collapse of other highway infrastructures including existing drainage system. According to Rangwala (2007), the planning and design of drainage (hydraulic) structures is one of the major aspect of highway engineering. A modern road construction consists of a well prepared subgrade to receive the sub-base course followed by base course and then finally the wearing course. A road may also be defined as an identifiable route, way or path between places which may be typically smooth, paved or otherwise prepared to allow easy travel. The need for expulsion of water from both surface and underground is highly imperative among several stages of road works.

The highway engineer is concerned to ensure that adequate arrangements are made for the surface water runoff from a pavement since otherwise pools of standing water may form, which will in time penetrate the structure of the pavement and cause premature failure (Watson, 1989).

The importance of drainage was realized by Roman road builders after the decline of highway construction in Europe and planned drainage became almost non-existed. With the advent of industrialization, increasing attention was paid to the removal of surface water and the lowering of the water-table beneath the pavement (Salter, 1988). Guptal et al (1991) emphasized that floods caused highway infrastructural decay in the following ways:

a. Softening of the subgrade, thereby reducing its bearing capacity.
b. Formation of gullies due to the erosion of side slopes and side drains
c. Softening of soil along the road which could lead to landslides.

Designer of every project must consider the hazards and benefits of precipitation and stream flow. Rainfall if not intercepted by vegetation or by artificial surface such as roofs, drains or pavements, falls on the earth and either evaporates, infiltrates or lies in depression storage. When the losses arising in these ways are provided for, there may remain a surplus that are obeying gravitational laws, flow over the surface to the nearest stream channel. The stream find their way into rivers, and the rivers find their ways into the sea. When rainfall is particularly intense or prolonged or both, the surplus runoff become large and water will ultimately fill and inundate the affected area and in so doing, cause great harm to the activities of men (Salter, 1988).

Singn (1983) and Rangwala (2007) explained that water should be prevented from reaching the road structure wherever possible or attempt should be made to remove it quickly from the road surface by laying well designed drainage system. Most significantly, it could be seen that the need for expulsion of water from both surface and underground is highly important among several stages of works.

In essence, the general function of highway drainage system is to remove rainwater from the road and water from the highway right-of-way (Mukherjee, 2014).

1.2 Study Area

Geographically, Oye Ekiti is within the tropics. It is located between longitude 7.797931 and latitude 5.328551. It has an average elevation of 546.91 meters (1794.32 feet). Oye Ekiti is a town and headquarter of Oye Local Government Area in Ekiti State, Nigeria. Oye Ekiti is bounded by Imojo Ekiti to the North, Ilupeju Ekiti to the East, Ayegbaju Ekiti to the West, and Are Ekiti to the South. It has a population of over 134 210 as of the 2006 census (http://en.m.wikipedia.org/wiki/oye-ekiti). Below is a map of Oye Ekiti where the study area is located.

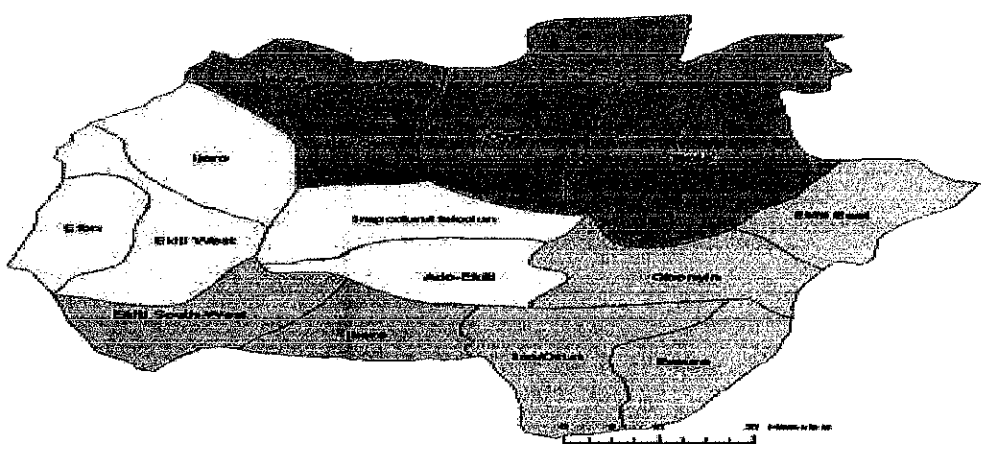

Plate 1.1: Ekiti map showing Oye Ekiti, the study area.

1.3 Problem Statement

Increased impervious surface is a consequence of urbanization, with correspondent and significant effects on the hydrologic circle. It is easily understood that an increased proportion of paved surfaces brings with it the followings:

a. Decreased in the infiltration rate
b. Shorter lag time between the onset of precipitation and resultant runoff

c. Increased in total runoff, thus, increasing the risk of flooding (Shuster et al., 2005)

Storm water management is aimed at reducing runoff of precipitation from impervious surfaces using drainage structures like line drains, culverts etc.

1.4 Justification

The land area at Irare Estate has been experiencing flooding of recent and thus, this study is conducted to find out what is responsible for this (through hydraulic analysis) and provide adequate solutions to forestall future occurrence of flooding (by structural design)

1.5 Aim and Objectives

The aim of this project is to assess and redesign the drainage structures from Babalola junction down to Ayegun river of Irare Estate, Oye Ekiti.

The objectives are to:

i. Conduct reconnaissance survey of the study area.
ii. Acquired the topographical map of the area contributing runoff to the drainage structures of the study area.
iii. Estimate the discharge and thus calculate the requisite cross-sectional area of the drainage structures, and
iv. Design appropriate drainage structures for waterways.

1.6 Scope of the Work

The assessment is carried out on a section of Irare estate (from Babalola junction down to Ayegun river). The area is virtually paved and occupied by residential buildings and locked up shops. The assessment will includes majorly:

a) Hydraulic analysis, and
b) Structural design

CHAPTER TWO

LITERATURE REVIEW

2.1 Drainage

The main objective of surface drainage is to remove rain from the carriage way as rapidly as possible so that traffic may move more safely and efficiently. The runoff formed, is a result of hydrological response of a natural catchment of precipitation which is altered radically when areas of land surface are impervious by the building of infrastructures and their effect on the production of runoff soon after the commencement of rainfall. There is a consequent decrease in the times of peak flow in the streams and an increase in magnitude of the peak, and total discharge volumes compared with pre-urbanization conditions. A less obvious effect on the stream flow is the reduction in base flow component since there is less percolation and recharge to groundwater (Shaw, 1985).

The consequences of urbanization feature widely in hydrological studies since they have an increase problem in recent years in both developed and underdeveloped countries. With the setting of a complexly new town, the planning of the urban development and the proportions of the impervious surfaces must be studied in order so assess the impact of rainfall event on drainage to rivers. In particular, the locations of possible floods must be identified and their frequency of occurrence determined. The change in flood characteristics due to urbanization depends on the nature of the initial catchment conditions and also on the severity of rainfall event (Hall, 1984).

Urban drainage system is poor in most of the developing countries. Gupta et al. (1991) mentioned that in some African countries that there is no urban drainage, where drainage system exists; it is filled with garbage and sediments. Wright et al. (1987) also mentioned this type of problem in Nigeria. Drainage is an important element in highway construction. Without a properly constructed and maintained drainage, the construction of a highway is just a waste of material, human and financial resources. Since highway engineering is concerned with the best use of resources to ensure a suitable road network to satisfy the need of society, the planning of highway with proper drainage is very essential.

According to Martin (1990), Egypt's drainage systems comprises of surface channels which receive flow discharge from sub-surface drain systems and which convey water to the pump stations that lift it either for re-use or for disposal into the Mediterranean Sea.

The planning of highway is done to achieve the following objectives.

1 To provide a most suitable type of maximum length with available funds.
2 To plan roads system for future anticipated requirements by constructing new road and improving the existing ones
3 If with available funds, required road system cannot be constructed, phased programme for roads development may be planned.
4 Highway planning helps to fix priorities of roads, but all the required roads cannot constructed. The most important should be constructed with suitable fund and within the plan period.
5 Planning is also helpful to work out financing system of roads (Singh et al., 1983).

Gupta et al. (1991) reported that highway drainage is highly essential, since the flow of surface water results from precipitation in the form of rain. Wright (1987) explained that a portion of the surface water infiltrates the soil, while the remainder stays on the surface of the ground and must be carried on, beside, beneath or away from the travelled way. He also stated that in certain instance, the control of underground water (groundwater) may be important, as in the case of an underground flow encountered in highway close to the ground.

2.2 Man and Hydrological Cycle

Man has tempered with every part of the hydrological cycle, groundwater is artificially recharged while natural precipitation is artificially modified under suitable conditions, runoff is stored behind dams and evapotranspiration losses are reduced through various activities. Hence, men's attempt to modify it usually have consequences throughout the working of the cycles, some of the consequences are known and maybe undesirable (Ayoade, 1988). Some of the ways in which man has influenced and continues to influence the hydrological cycles are through weather modifications, urbanization, rural land use and water resources development projects.

2.2.1 Hydrological Analysis

Lohani (2007) defined hydrology as the circulation of water and its constituents through the hydrologic cycle. It deals with precipitation, evaporation, infiltration, groundwater flow, runoff, stream flow and the transport of substances dissolved or suspended in flowing water.

A hydrological analysis of the area to be drained is an essential element in the design of highway drainage. This type of study supplies information on runoff and stream characteristics which is used as a basis of hydraulic design. The design flow is established by selecting the proper combination of rainfall and runoff characteristics that can be reasonably expected to occur. This is usually further restricted by establishing an interval of time or frequency period as the basis of design. The design criteria would then determine the maximum flow carried by the drainage structure with no flooding or a limited amount of flooding to be exceeded on the average of one during a design period (FMT, 1973).

2.2.2 Precipitation

Precipitation is liquid or solid water falling from cloud to the earth's surface (Borzenkova, 2002). Some moisture is always present in the atmosphere, it is stored in the atmosphere, awaiting forces that can cause precipitation. According to Martin (1990), there are four conditions that must be present for the occurrence of precipitation:

i. Condensation onto nuclei
ii. Cooling of the atmosphere
iii. Growth of water droplets and
iv. Mechanism to cause a sufficient density of the droplets.

All these conditions can occur in a relatively short time period and may be observed simultaneously.

2.2.3 Forms of Precipitation

Snow: Snow is a complex ice crystals. A snowflakes consists of agglomerated ice crystals. The average water content of snow is assumed to be 10% of an equal volume of water.

Hailstones: are balls of ice that are about 5 to over 125mm in diameter. Their specific gravity is about 0.7 to 0.9. Thus, hailstones have the potential for agriculture and other property damage.

Sleet: results from the freezing of raindrops and is usually a combination of snow and rain.

Rainfall: Rainfall is the amount of precipitation expressed as the depth in centimeters (cm)

2.2.4 Rainfall

Rainfall is the only form precipitation found in the project area. Rainfall is the amount of precipitation expressed in the depth in centimeters (cm). It is measured by rain gauge. Birdie and Birdie (1992) gave the different types of rain gauge as:

i. Standard rain gauge
ii. Syrion's rain gauge and
iii. Automatic recording rain gauge.

In order to compute the average rainfall over a basin or catchment area containing more than one rain gauge station, the computation of average precipitation or rainfall may be done by:

a. Arithmetic average method
b. Theissen polygon method and
c. Isohyetal method

2.2.5 Rainfall Intensity

Rainfall intensity as defined by Sharma and Shanna (1990), is the rate at which rainfall occur and expressed in depth unit per unit time. It is the ratio of total amount of rainfall to the duration of rainfall.

Rainfall intensity is classified into:

i. Light intensity which is less than 2.5mm/hr.
ii. Moderate intensity which ranges between 2.5mm and 7.5 mm/hr. and
iii. Heavy intensity which is over 7.5mm/hr

Rainfall intensity during the design storm is a function of the occurrence duration and intensity.

2.2.6 Time of Concentration

The time of concentration is the longest travel time taken by a particle of a water to reach a discharge point in a watershed. It is the longest travel time between a point on the watershed to the point of interest. It varies with the depth of rainfall excess in the watershed at any time. It can also be said to be the duration of rainfall required to produce the maximum rate of runoff (Shaw, 1985).

The time of concentration is estimated by the formula:

$$t = \frac{0.0Q78(L)^{0.77}}{S^{0.5}} \qquad \text{.........} 2.1$$

Where:

t = time of concentration

L = the length of the watershed area in feet

S = slope of the watershed area in feet

2.3 Watershed Area

Watershed area or river basin or drainage basin or catchment area is defined as an area of land that drains all the streams and rainfall to a common outlet such as a outflow of a reservoir, mouth of a bay, or any point along a stream channel (www.water.usgs.gov/edu/watershed.com). The pattern of the tributary system depends on various factors such as physical characteristics of the area, nature of rock formation and their erodibility (Sharma and Shanna, 1990).

Various classification of watershed area are:

1 Trex-like type
2 Rectangular type
3 Radial type
4 Trelis type
5 Fern-shape type
6 Parallel type
7 Tern-bit type

2.4 Runoff

The runoff of a catchment or watershed area in any specified period is the total quantity of water drained into a stream or into a reservoir in that period (Punmia et al, 1990). However, Babalola (2009) explained further that when rainfall forms part of the water entering the soil through infiltration probably as the rain continues, the rate of infiltration will be reducing leading to a volume of water forming on the earth surface. Part of surplus water which is retained on earth surface and flow is referred to as runoff. The most important single factor that affects the runoff is the nature of the rainfall especially the magnitude, time and distribution, A heavy rainfall with high intensity will give a greater runoff than a slight rainfall with low intensity, this is because less amount of intensity will infiltrate into the soil while that of high intensity has a better chances of running off. The duration of the rainfall is very important because the longer the duration of the rainfall, the larger the amount of the total rainfall and this will make the soil saturated more easily with excess rainfall appearing as runoff (Isinkalu-Ajayi, 2000).

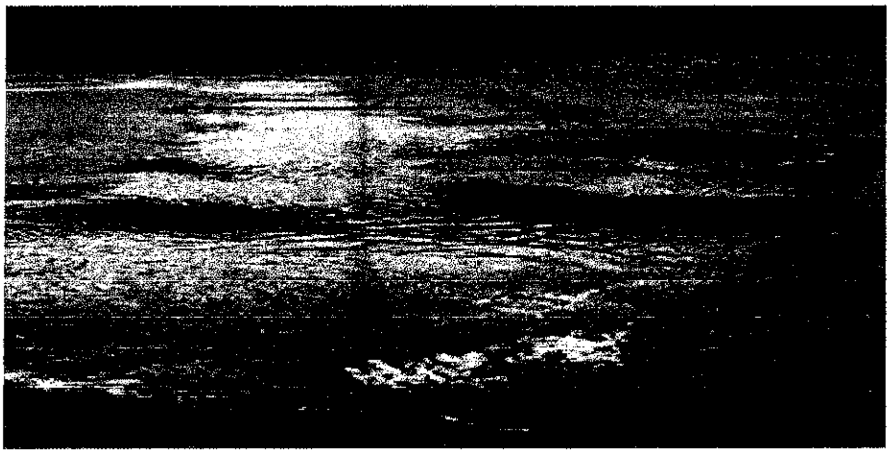

Plate 2.1: Surface runoff

2.4.1 Human Contribution to Rate of Runoff

Man by his activities often set off the process of flooding and has greatly influenced its development. He is an important factor in accelerating runoff rate, be it directly or indirectly. His negative effect is felt by the destruction of natural vegetative cover of the soil. The ultimate cause of accelerated runoff rate is the human interference in the natural ecosystem balance in such a way as indiscriminate removal of vegetative cover including grasses. Therefore each time land is cleared of its vegetation for agriculture and social development need, without necessary counter-measures, the land is exposed to flooding by water from rain. Also the prime sources of accelerated runoff include road construction, timber exploitation, urbanization, exposed arable crop land overgrazed and fire ravaged area. Sometimes road construction obstructs or diverts the direction of flow of water or increases its force. Bad road construction bares most of the surrounding lands without adequate protection or sound drainage system. Excavation of sand or laterite from unauthorized places especially from end of gullies for building or road construction contribute to flood and erosion hazards (Isinkalu-Ajayi, 2000).

2.4.2 Environmental Contribution to Formation of Runoff

Increase in human activities have a great effect on the formation of runoff. The roofs, concrete floors and some newly constructed roads in an area serve as impervious layers. This is because rains that sank into the ground previously now run quickly over the surface (increased rate of runoff). This in turn increases quantity of runoff mostly when the rain is prolonged, the surplus runoff becomes large, far more than the drains can convey which therefore, fill up and overflow the drain and this may cause a great harm to human activities (The Center for Neighborhood Technology, 2014).

2.5 Side Slopes and Side Ditches

Side slopes are provided in cut sections in highway locations in rural areas to provide for surface drainage while side ditches maybe constructed along embankment section when needed to supplement natural channels, both flat bottomed and v-section ditches are used. Flow of water inside ditches occurs in direction that is generally parallel to the roadway center line. Grades used in open ditches provide open channels for the removal of surface water from within the limits of highway right-of-way. At times areas adjacent to the right of way may also contribute to the flow. Some of the ways to prevent erosion of shoulders and side slopes are the provision of curbs, gutter and flumes and intercepting ditches.

2.6 Kerb and Gutters

They are essentially provided in the street pavement for quick disposal of stream water.

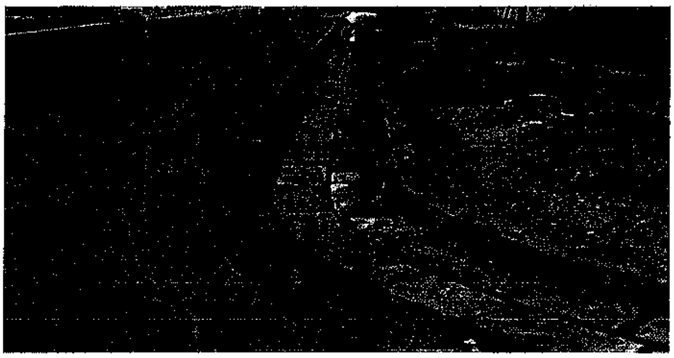

Plate 2.2: Kerb and gutter

2.7 Pipe Drains

The side drains are normally covered when road runs along populated areas. These covered drains maybe of concrete pipes stones ware pipe, C.I. or G.I. pipes. Sometimes corrugated metal pipes are also used for this purpose.

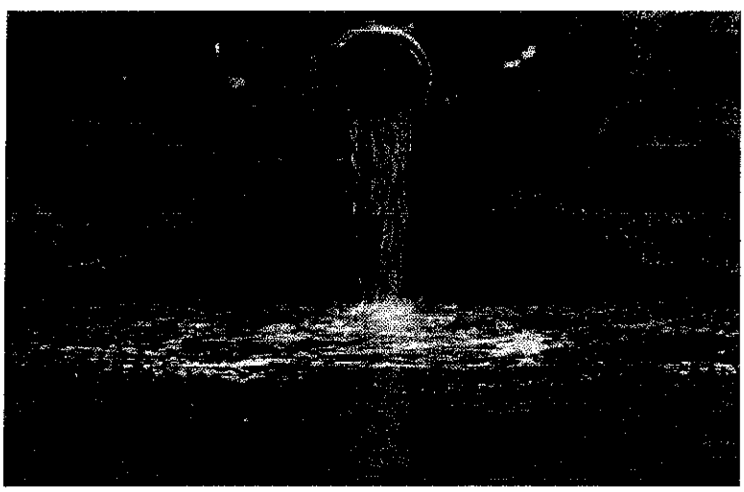

Plate 2.3: Pipe drain

2.8 Drainage Design

Gichaga (1982) explained that storm water design involves the estimation of the amount of surface water expected and the design of a facility capable of disposing off that quantity of water without causing damage to the adjacent property or to the environment.

However, O'Flaherty (1974) affirmed this by saying that to fully study a surface drainage; first of all, there is the problem of deciding the-amount of water which must be catered for i.e. the amount of water arriving at the inlet, drainage or culvert and to handle this water.

Therefore storm water drainage design requires;

i. Hydraulic analysis which is estimating the expected amount of runoff.
ii. Hydraulic design which is determining the required facility to accommodate the amount of run off estimated at the hydraulic analysis stage.

2.9 Hydraulic Analysis

Hydrological analysis should be carried out to determine the peak discharge of watercourse where the projects roads, culverts and channel intersect in order to check sizing of drainage structures. There are two basic approaches to the calculation. Firstly is by computing runoff as related to rainfall after abstractions for infiltration and retention losses and for temporary detention losses. The method that has been applied for many years is the rational method and the second is basic to the development of accurate and economically applicable methods.

2.9.1 Hydrograph Method

A hydrograph is a graph of flow rate versus time. It consist of both surface (overland) and groundwater flows that infiltrate from the ground to the surface conduit. Ground water inflow that is relatively persistent overtime is called base flow. Groundwater flows for shorter period of time are sometimes called interflow.

A typical surface runoff hydrograph consist of three part:

i. Rising limb or concentration curve
ii. Peak discharge or crest segment
iii. Falling limb or recession curve (Martin, 1990).

2.9.2 Properties of Hydrograph

Lag time (L): The time interval from start of mass of rainfall excess to the peak of the resulting hydrograph.

i. Time to peak (t_p): The time interval from the start of rainfall excess to the peak of the resulting hydro graph.
ii. Time of concentration (t_c). The time interval from the end of rainfall excess to the inflection point (change of slope) on the recession curve.
iii. Recession time (t_r). Time from the peak to the end of surface runoff.
iv. Time base (t_b). Time from the beginning to the end of surface runoff.

2.9.3 Flooding Frequency Method

Flood frequency method means the number of times a flood of given magnitude will be equaled or exceed in any one year and it is usually in term of recurrent interval or return period. Recurrence interval is the number of years during which flood of given magnitude will be equaled or exceed once. It is usually denoted by T_r and given by:

$$T_r = \frac{100}{F} \quad \text{...2.2}$$

Where

T_r = recurrence interval, and

F = frequency

The recurrence interval for a flood of a given magnitude maybe determined if the record of maximum flood discharge in each year of n number of years is given. The flood discharge arc arranged in the descending order of magnitude and assigned in serial numbers. Thus the highest Hood Is placed at the top and given serial number 1, next highest is given serial number 2 e.t.c.

The lowest flood discharge will be at the bottom with serial number n. For a particular flood with serial number (m), then its recurrence interval can be found by any of the following methods:

i. California method (1923)

$$T = \frac{n}{m}$$

ii. Allen Hazen method (1930)

$$T = \frac{2n}{2m + I}$$

iii. Weilbul method (1939)

$$T = \frac{n + I}{m}$$

iv. Gumbel method

$$T = \frac{n}{m + c^{I}}$$

Where

n = number of event i.e. year of record

m = order of rank of the event when flood magnitude are arranged in descending order.

I = recurrence interval

c = gumbed correction factor (Modi, 1990).

In order to find flood discharge of desired frequency, a plot of flood discharge versus F or frequency is prepared on a probability paper. From this plot, any value of the flood discharge maybe determined. The application of this method involves the determination of peak discharge of various frequencies of maximum rainfall of various durations for storm drainage design and study the meteorological and hydrological drought frequencies (Modi, 1990).

This frequency method also suffers from the following inherent drawbacks:

a. It does not give good result for obtaining flood discharge for such values of recurrence interval, which exceed the number of years for which records are not available
b. It cannot be adopted for reservoirs project.
c. The probable errors of estimating an extreme flood e.g. a 10 years from 50-60 years record are so large that the method may become useless.

2.9.4 Empirical Formulae

Several empirical formulae have been developed for estimating the maximum or peak value of the hood discharge. In this formula, the maximum flood discharge, Q of a river or stream is expressed as a function of the catchment area, A. Most of these formulae may be written in a general form as

Q = C A...2.3

Where

C = Coefficient of runoff'

n = index, the value of which depends on the size and location of the catchment.

One of the formulae which is commonly used is indicated below:

$Q = CA^{\frac{1}{4}}$ (Dickens formula)...2.4

Where

Q = maximum flood discharge in m/s

A = area of catchment in km^2

C = coefficient whose values depend on the climate and catchment characteristics.

The rational formula is actually an increased version of the above formula as it incorporates the effect of more of the factors that influence Hood.

2.9.5 Rational Method

The concept of rational method for determining flood peak discharged from measurements of rainfall depths own its origin to Mulvancy and Irish engineers, who were concerned with hand drainage. Some Americans attributed first mention of the formula to one of their engineer engaged in sewer design (O'Flaherty, 1974). The use of the rational formula is sometimes referred to as the Lloyd-Davies method. The rational formula used to estimate the maximum flood discharge is

$$Q = C\,I\,A \qquad \text{2.5}$$

Where

Q = maximum flood discharge in hectares meter per hour or cubic meters per hour.

A = area of the drainage basin in hectares or square meters

C = runoff coefficient, a measure of the impermeability of the drainage area.

I = critical intensity or design intensity of rainfall in meters per hour corresponding to the time of concentration.

2.10 Calculating the Waterway Opening of Drains

To estimate the cross-sectional area of drains, Talbot's formula can be used. The formula is given by

$$\alpha = CA^{o.75} \qquad \text{2.6}$$

Where

a = waterway opening or cross-sectional area (in square ft.)

C = Talbot's coefficient which depends upon the nature of surface

A= Catchment area in acres

2.11 Structural Design

Structural design deals with proportioning of members to resist the applied force (Ayodele, 1990). The structure in question must be able to carry all normal load safely during construction and in service and should have adequate durability. They should also be able to resist the effect of accident and misuse .Retaining structures such as walls are useful within the built environment especially at bridge sites, river bank area and even within the house in a sloppy terrain. BS8110 (1997) gives the analysis of designing retaining structure such as line drain. A retaining structure must support its backfill without detrimental lateral movement and the surface of the backfill must not settle unduly. Water retaining structures like culverts must be able to withstand the imposed loads, its own weight and hydrostatic pressure of the liquid passing at any instant of time.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Theoretical Background

Floods are some of the largest natural disasters known to humanity and statistics shows that around 70% of all global disasters are linked to hydro-meteorology events (APFM, 2004). Throughout history, they have periodically inflicted serious damage on society (Biswas, 2006). They caused huge misery, especially in developing countries, where low-income economies are greatly stressed by flood recurrence. It is obvious that adequate flood management should be considered of utmost importance in the study area.

3.2 Materials Design and Preparation

Some of the materials used to carry out this study were:

1) Google Earth Image (plan and profile) of Irare estate showing the study area: Google Earth is a computer program that renders a 3D representation of Earth based on satellite imagery. The program maps the Earth by superimposing satellite images, aerial photography, and GIS data onto a 3D globe, allowing users to see cities and landscapes from various angles.

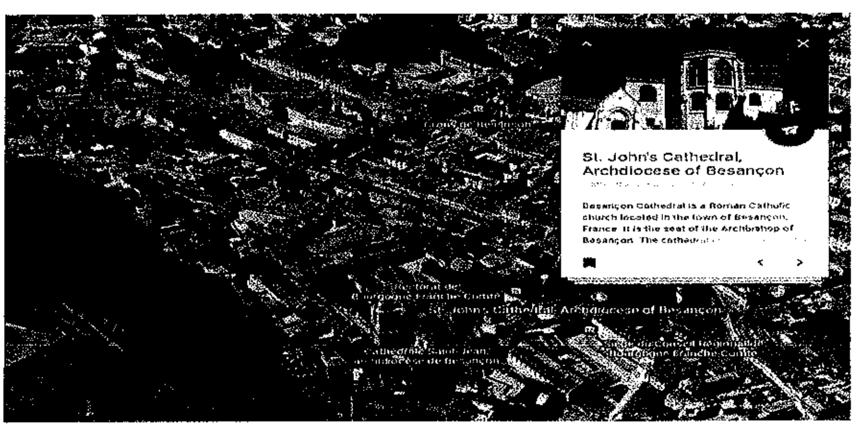

Plate 3.1: Google earth image

2) Odometer: An odometer is an instrument used for measuring the distance travelled by a vehicle, such as a bicycle or car. The device may be electronic, mechanical, or a combination of the two.

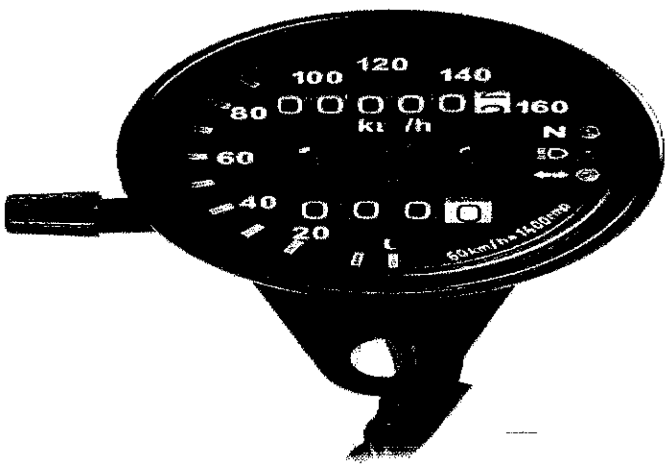

Plate 3.2: An odometer

3) Leveling equipment (Dumpy Level): The dumpy level is mainly used in surveying for the following purposes:
   a. To determine relative height and distance among different locations of a surveying land.
   b. To determine relative distance among different locations of a surveying land.

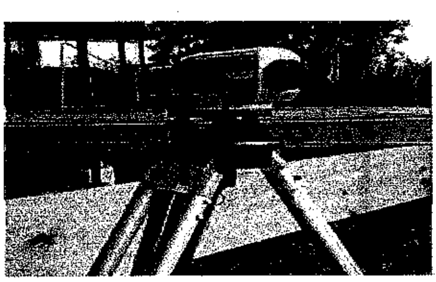

Plate 3.3: Dumpy level

4) Measuring tape: A tape measure or measuring tape is a flexible ruler and used to measure distance.

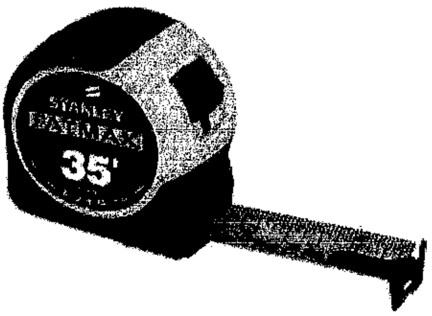

Plate 3.4: Measuring tape

5) Topographical map of Oye-Ekiti: A topographic map is a type of map characterized by large-scale detail and quantitative representation of relief, usually using contour lines. These maps depict in detail ground relief (landforms and terrain), drainage (lakes and rivers), forest cover, administrative areas, populated areas, transportation routes and facilities (including roads and railways), and other man-made features (Natural Resources Canada)

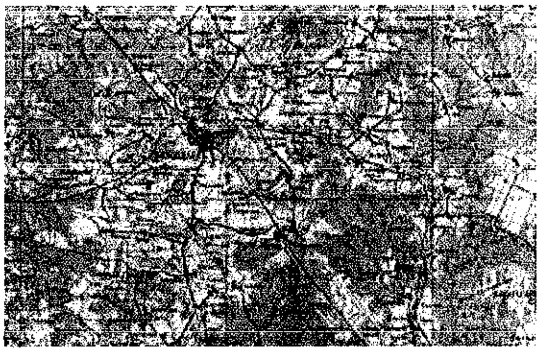

Plate 3.5: Topographical map

3.3 Reconnaissance Survey

The study area was visited to familiarize with the existing situations and to take note of the peculiarity of the catchment contributing runoff to the specific area of study which spans from Babalola junction through Oniyelu house to the outfall at Ayegun river of Irare Estate, Oye Ekiti.

The sizes of the existing drains and culverts were noted. The type of catchment area cover (in terms of grasses, paving (in concrete or asphalt)) was also noted. The outlay, pattern and direction of flow of the runoff was carefully studied.

3.4 Preliminary Survey

The Google Earth Image (plan and profile) of Irare estate was gotten from the internet which gave a bird-eye view of Irare estate in general and the study area in particular. The drains conveying the runoff from the catchment area to the outfall was identified on the plan before the drain's profile was also shown.

Later, a survey team was on site to do some measurements. The odometer as one of the instruments was used to take linear dimensions on the ground. The Dumpy Level (a leveling instrument) was used to take the spot heights along the lined drains to confirm the slope of the drains. It was also used to estimate the slope of the entire area from Babalola junction down to Ayegun river. The measuring tape was used to take the dimensions of the cross-sections of the drains and culverts in terms of depth and widths.

Oye-Ekiti topographical map of scale 1:50,000 was acquired from Ekiti State Ministry of Land and Housing, Ado-Ekiti. A desktop analysis was carried out on the map where the study area was isolated and the catchment area was estimated with due regard to the scale.

3.5 Estimation of Runoff and Waterway Opening

Two established formulae were considered here. They are:

1. The Rational formula given by:

$$Q = CIA \quad \text{.......} \quad 3.1$$

Where

Q = discharge in m^3

C = catchment area co-efficient

I = rainfall intensity

A = catchment area

2. The Talbot's formula given by:

$$a = CA^{0.75} \quad \text{.......} \quad 3.2$$

Where

a = waterway opening or cross-sectional area (ft^2)

C = catchment coefficient of runoff

A = catchment area (acres).

For the purpose of this project, the Talbot's formula was adopted to estimate the required cross-section areas of the existing drains at specified points because of its simplicity in calculating the cross-section.

The measured and calculated cross-sectional areas were compared to find out whether the capacity of the existing drains are adequate or not.

3.6 Structural Design

The structural loading, structural analysis and design of sections where the cross-sectional areas of the drains are not adequate were carried out according to BS8110, BS5400 and with the information from *Reinforced Concrete Designer's Handbook* by Reynolds, C.E. and Steedman, J.C. (1999).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Reconnaissance Survey

Table 4.1 shows the division of the study area into sections and drainage areas. From the table, section 1 has Babalola junction down to Oniyelu house as its drainage area while section 2 has Oniyelu house down to Lash house as its drainage area. The drainage area for section 3 is from Lash house down to Ayegun river. The reconnaissance survey also showed that the study areas slopes from Babalola junction through Oniyelu house, Lash house into the Ayegun river which is the outfall. Below is table 4.1 showing the division of the study area into sections.

Table 4.1: Division of study area into sections and drainage areas

Section	Drainage Area
1	Babalola junction to Oniyelu house
2	Oniyelu house to Lash house
3	Lash house to Ayegun river

4.2 Preliminary Survey

Figure 4.1 shows the Google Earth image of part of Irare estate where the study area is located. The figure shows the aerial view and the vertical profile of the existing line drains. The drains positions are indicated by red lines on the aerial view starting around Babalola junction and ending at Ayegun river. Plate 4.1 shows the area view of the study area as shown from Google Earth Image software

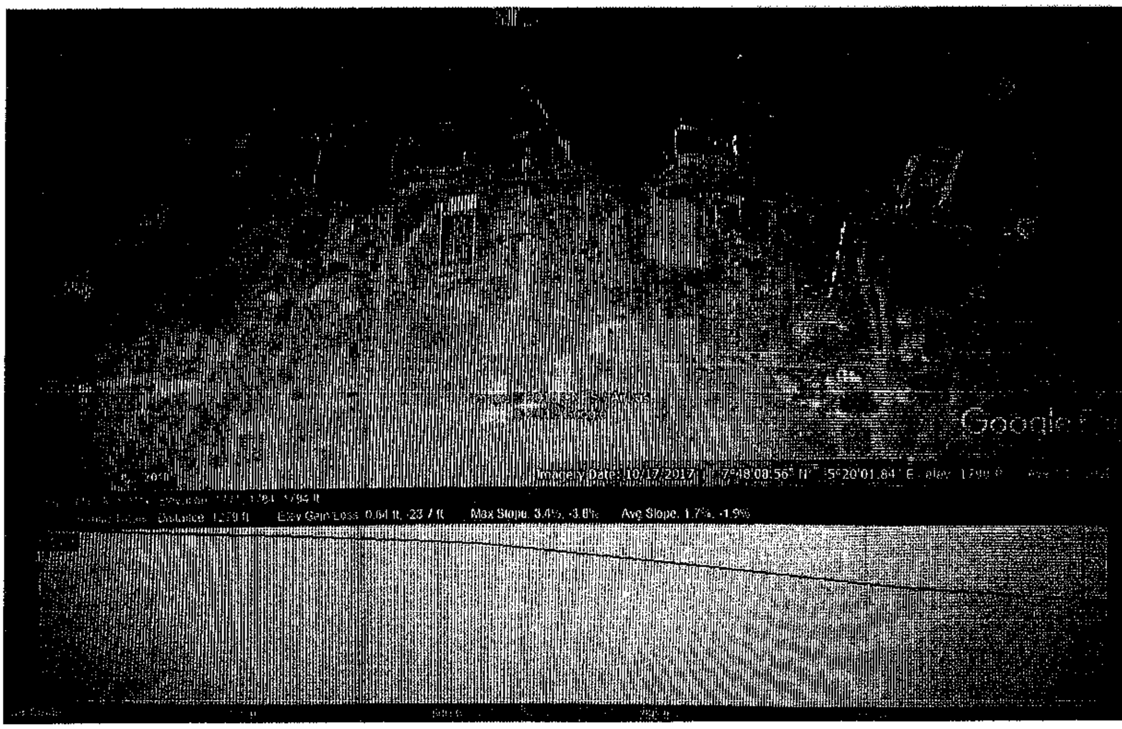

Plate 4.1: The Google Earth Image (plan and profile) of the study area at Irare estate

The drain's length is about 394.34m, the average slope 1.7% and the elevation from the mean sea level is 598m (Google Earth, 2017). The levelling activities just helped to confirm some of the information gotten from Google Earth image. From the spot-heighting activities, the average slope estimated is 1.9% as against the 1.7% of the Google Earth and the odometer measurement gave 404m. Table 4.2 is showing the results of the analysis of the existing line drain cross-section measurements. With reference to table 4.1 and with respect to table 4.2, section 1 which includes Babalola junction to Oniyelu house area discharge into a drain of 237m long with a cross section of $0.21m^2$. Similarly, section 2 which includes Oniyelu house down to Lash house area discharge into a drain of 51m long with a cross-section area of $0.23m^2$ while section 3 includes Lash house down to Ayegun river area discharging into a drain of 116m with no cross-section because of the absent of a well-defined drain. From this analysis, it can been seen that total length of the drain is 404m.

Table 4.2: Result of cross-sectional area analysis of existing drains

Section	Length (m)	Width (m)	Depth (m)	Area (m^2)
1	237	0.53	0.39	0.21
2	51	0.52	0.45	0.23
3	116	____	____	____

4.3 Estimation of Runoff and Waterway Opening

From the topographical map, the shaded area which is also the catchment area of the study area is estimated to be 23 cm^2. The scale of the map is 1:50,000.

The implication of this is:

1 cm on the map represent 50,000 cm on the ground

That is, 1 cm on paper = 500 m on the ground

Then, squaring both sides, we have;

$(1\ cm)^2 = (500\ m)^2$

A full square area, $1\ cm^2 = 250{,}000\ m^2$

But 5 holes = 1 cm = 500 m

Then, 1 hole $= \frac{1}{5}\ cm = \frac{500}{5}\ m$

1 hole = 0.2 cm = 100 m

Squaring both sides; $(0.2\ cm)^2 = (100\ m)^2$

1 hole area, $0.04\ cm^2 = 10{,}000\ m^2$

From the catchment area, we have 23 full squares (using a transparent graph paper)

$23 \times 250{,}000 = 5{,}750{,}000\ m^2$

$= 1437.5$ acres (since $4000\ m^2 = 1$ acre)

Estimating the waterway opening (cross-sectional area) of drain using Talbot's formula

$$a = CA^{0.75}$$

where

a = waterway opening

C = Talbot's coefficient of runoff

A = catchment area (in acres)

Substituting values,

$$a = 0.4 \times 1437.5^{0.75}$$

$$= 93.38 \text{ ft}^2$$

$$= 8.67 \text{ m}^2 \quad (\text{since } 1 \text{ ft}^2 = 0.0929 \text{ m}^2)$$

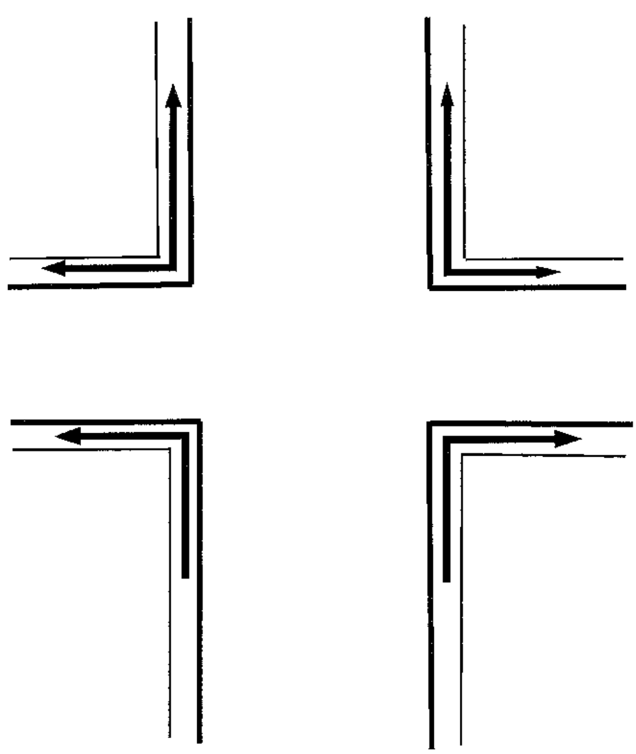

Figure 4.1: Layout of an intersection showing direction of runoff in drains

From figure 4.2, the runoff flows in six (6) directions

$$8.67 \div 6 = 1.44 \text{ m}^2$$

The required cross-sectional area = 1.44 m^2 > 0. 21 m^2 (the existing cross-sectional area of most of the drains)

If the depth of the drain is assumed to be, d = 1.5 m

Then, the width, $w = \frac{1.44}{1.5} = 0.96$ m

= 1 m (approximately)

Let use 1.5m for the width (provided width)

The provided cross-sectional area =1.5 × 1.5 = 2.25 m^2 > 1.44 m^2 (the required)

Therefore, the provided cross-sectional area is o.k.

From this calculation and with reference to table 4.2, the cross-sectional area of drains of sections 1, 2 and 3 of the study area should be 2.25 m^2 minimum. The recommended cross-sectional areas of the drain are stated in table 4.3.

Table 4.3: Recommended cross-sectional areas of the drains

Section	Length (m)	Width (m)	Depth (m)	Area (m^2)
1	237	1.50	1.50	2.25
2	51	1.50	1.50	2.25
3	116	1.50	1.50	2.25

4.4 Structural Design

The structural analysis and design of the culvert and line drain are carried out in the appendices using British codes BS 8110 and BS 5400

CHAPTER FIVE

CONCLUSION AND RECONMMENDATIONS

5.1 Conclusion

The assessment of the study area revealed the followings:

1. The investigated area consisted of three sections with their drainage areas
2. The drainage area for section 1 is Babalola junction to Oniyelu house, for section 2 is Oniyelu house to Lash house and for section 3 is Lash house to Ayegun river.
3. The total drain's length is about 404m, the average slope is 1.9% and the elevation from the mean sea level is 598m.
4. The lengths of existing drains at section 1 is 237m with average cross-sectional area of $0.21m^2$, that at section 2 is 51m with average cross-sectional area of $0.23m^2$, while that of section 3 is 116m with no pronounced drain.
5. The required cross-sectional areas for drains at sections 1,2 and 3 are $2.25mm^2$, $2.25mm^2$ and $2.25mm^2$ respectively.
6. The reinforcements for the culverts are Y16@200mm $^c/_c$ as main bars and Y12@300mm $^c/_c$ as distribution bars.
7. The reinforcements for the line drains are Y16@200mm $^c/_c$ as main bars and Y10@300mm $^c/_c$ as distribution bars.

5.2 Recommendations

The following are recommended based on the findings in the course of this project:

1. The existing drains and culverts should be demolished and reconstructed.
2. The average cross-sectional areas at sections 1, 2 and 3 should be redesigned to $2.25mm^2$.
3. Concrete grade $25N/mm^2$ (Mix ratio 1:2:4) should be used for drains and culverts.
4. High yield reinforcements Y16@200mm centre to centre should be used as main bar and Y12@300mm centre to centre as distribution bar for the culvert.

5. High yield reinforcements Y16@200mm centre to centre should be used as main bar and Y10@300mm centre to centre as distribution bar for the line drains.

With all these recommendations carried out, the incidences of flooding at the study area will be a thing of the past.

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APPENDICES

APPENDIX A

BOX CULVERT

Table A-1: Design Information

Relevant building and design codes	1. BS 8110 The structural use of concrete, part 1 & 3 2. BS 5400 Steel, concrete and composite bridges 3. Reinforced concrete designer's handbook by Reynolds and Steedman 4. Steel designers manual
General loading conditions	30 units of HB loading at 2.5kN/wheel = 30 × 2.5 = 75kN
Exposure condition	Severe (both internally and externally)
Material data	Characteristics strength of reinforcement, F_y = 460N/mm^2 Characteristics strength of concrete, F_{cu} = 25N/mm^2 Concrete cover, Φ = 40 mm
Dimensions	Width, B = 1.5m Depth, D = 1.5m Length of culvert = width of the road = 7.3m
Other relevant information	Self-weight of concrete = 24kN/m^3 Bulk density of soil = 18kN/m^3 Coefficient of active pressure of soil = 0.33 Slab thickness = 200mm

Assumed diameter of tension bar, $\varnothing$ = 16mm

Effective depth, d_{eff} = overall depth – cover – $\frac{\varnothing}{2}$

$= 200 - 40 - \frac{16}{2}$

d_{eff} = 152mm

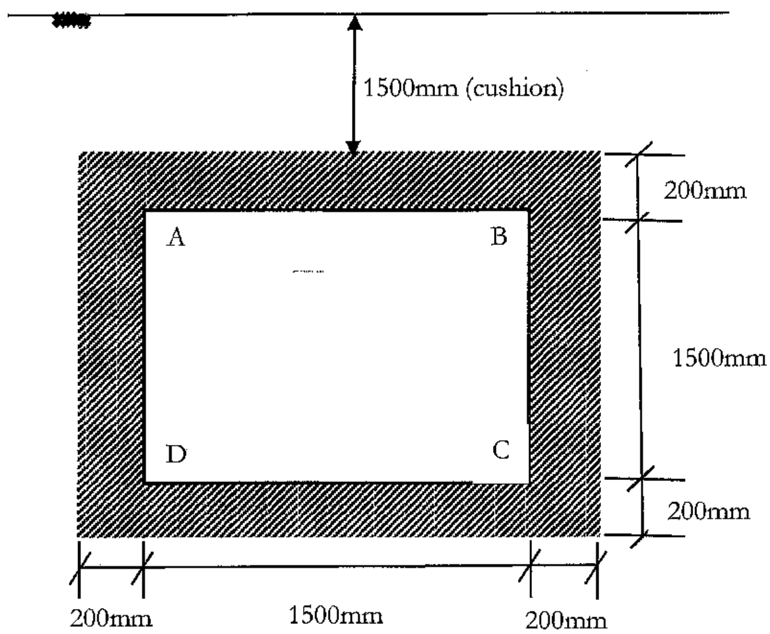

Figure A-1: Loading on the box culvert

(A) LOAD CALCULATION

Top slab:

From HB loading, each unit is 2.5Kn

Therefore, 30 units of HB loading = 30 × 2.5 = 75kN

Total slab live load = 75kN

Dead load:

Slab own weight = 0.2 × 24 = 4.8kN/m

Total design load, Q = $1.4g_k + 1.6q_k$

= (1.4 × 4.8) + (1.6 × 75)

Q = 126.72kN/m

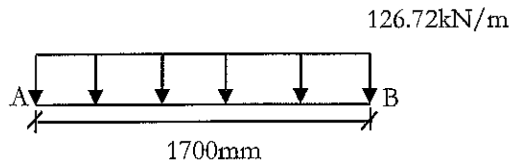

Figure A-2: Top slab loading

Bottom slab:

Top slab load = 126.72kN/m

Wall weight = 2 (0.2 × 24 × 1.4) = 13.44kN/m

Bottom slab self-weight = (0.2 × 24 × 1.4) = 6.72kN/m

Total weight on bottom slab = 126.72 + 13.44 + 6.72 = 146.88kN/m

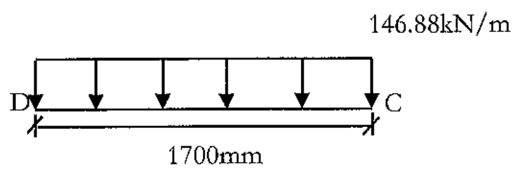

Figure A-3: Bottom slab loading

Side walls:

Assuming $\Theta = 30^0$

Coefficient of active pressure, $Ke = \frac{1-\sin\theta}{1+\sin\theta}$

$$Ke = \frac{1-\sin\theta}{1+\sin\theta}$$

$$Ke = 0.33$$

Pressure due to live load surcharge equivalent to 1.2m height of earth on both sides fills = $1.2 \times 18 \times 0.33 = 7.128kN/m^2$

Pressure due to earth surcharge = $1.5 \times 18 \times 0.33 = 8.91kN/m^2$

Pressure due to earth fill = $1.7 \times 18 \times 0.33 = 10.098kN/m^2$

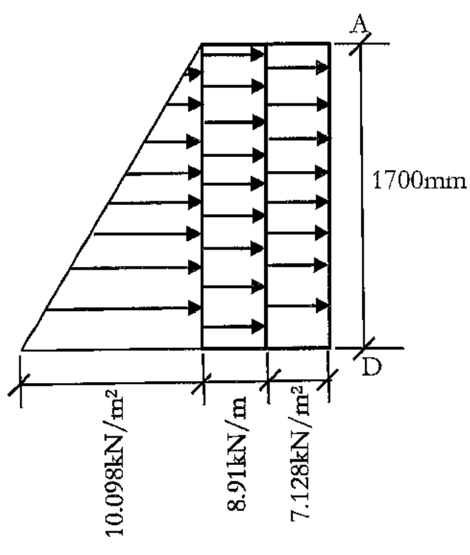

Figure A-4: Side Wall Loading

(B) SHEAR CALCULATION

Top slab:

$$V_{AB} = V_{BA} = \frac{WL}{2} = \frac{126.72 \times 1.7}{2}$$

$$V_{AB} = V_{BA} = 107.71kN$$

Side walls:

$$V_{AD} = V_{BC} = \frac{(8.91+7.128)\times1.7}{2} + \frac{10.098}{3} - \frac{(20.90-17.14)}{1.7}$$

$$= 13.63 + 3.366 - 2.21$$

$$V_{AD} = V_{BC} = 14.79kN$$

$$V_{DA} = V_{CB} = \frac{(8.91+7.128)\times1.7}{2} + \frac{2\times10.098}{3} + \frac{(20.90-17.14)}{1.7}$$

$$= 13.63 + 3.366 + 2.21$$

$$V_{DA} = V_{CB} = 22.57kN$$

Bottom slab:

$$V_{DC} = V_{CD} = \frac{WL}{2} = \frac{146.88\times1.7}{2}$$

$$V_{DC} = V_{CD} = 124.85kN$$

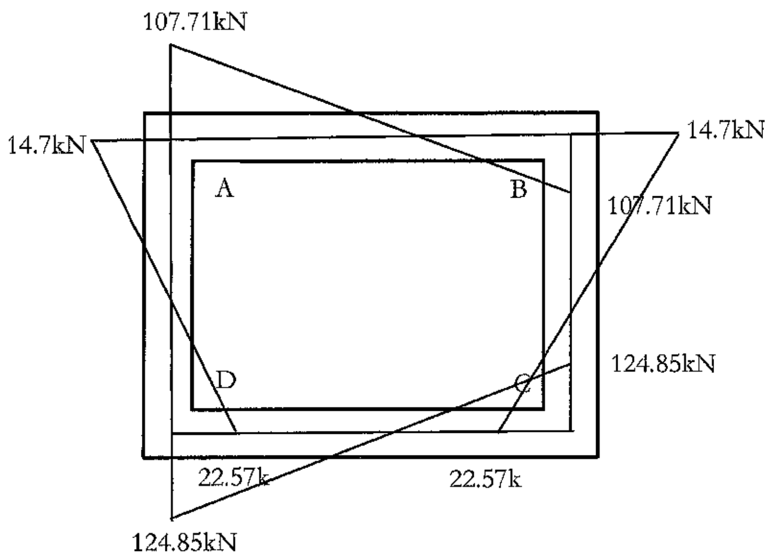

Figure A-5: Shear force diagram

(C) MOMENT CALCULATION

Top slab:

Fixed end moment due to dead load $= \frac{WL^2}{12} = \frac{(4.8 \times 1.4) \times 1.7^2}{12}$

$= 1.618\text{kNm}$

Fixed end moment due to live load $= \frac{WL^2}{12} = \frac{(75 \times 1.6) \times 1.7^2}{12}$

$= 28.9\text{kNm}$

Total fixed end moment = 1.618 + 28.9 = 30.52kNm

Mid-span moment due to dead load $= \frac{WL^2}{8} = \frac{(4.8 \times 1.4) \times 1.7^2}{8}$

$= 2.43\text{kNm}$

Mid-span moment due to live load $= \frac{WL^2}{8} = \frac{(75 \times 1.6) \times 1.7^2}{8}$

$= 43.35\text{kNm}$

Total mid-span moment = 2.43 + 43.35 = 45.78kNm

Bottom slab:

Fixed end moment $= \frac{WL^2}{12} = \frac{146.88 \times 1.7^2}{12}$

$= 35.37\text{kNm}$

Mid-span moment $= \frac{WL^2}{8} = \frac{146.88 \times 1.7^2}{8}$

$= 53.06\text{kNm}$

Side walls:

Fixed end moment at top due to dead load $= \frac{WL^2}{12} + \frac{WL^2}{30}$

$= \frac{8.91 \times 1.7^2}{12} + \frac{10.098 \times 1.7^2}{30}$

$= 2.15 + 0.97$

$= 3.12\text{kNm}$

Fixed end moment at top due to live load $= \frac{7.128 \times 1.7^2}{12}$

$= 1.72\text{kNm}$

Total FEM at top = 3.12 + 1.72

= 4.84kNm

Fixed end moment at base due to dead load = $\frac{8.91 \times 1.7^2}{12} + \frac{10.098 \times 1.7^2}{20}$

= 2.15 + 1.46

= 3.16kNm

Fixed end moment at base due to live load = $\frac{7.128 \times 1.7^2}{12}$

= 1.72kNm

Total FEM at base = 3.61 + 1.72

= 5.33kNm

Mid-span moment due to dead load = $\frac{WL^2}{8} + \frac{WL^2}{16}$

$= \frac{8.91 \times 1.7^2}{8} + \frac{10.098 \times 1.7^2}{16}$

= 3.22 + 1.82

= 5.04kNm

Mid-span moment due to live load = $\frac{WL^2}{8}$

$= \frac{7.128 \times 1.7^2}{8}$

= 2.57kNm

Total mid-span moment = 5.04 + 2.57

= 7.61kNm

(D) DISTRIBUTION FACTORS

Stiffness:

$K_{AB} = \frac{4EI}{L} = \frac{4EI}{1.7} = 2.35EI$

$K_{BC} = \frac{4EI}{1.7} = 2.35EI$

$K_{CD} = 2.35EI$

$K_{DA} = 2.35EI$

At joint A:

$$DF_{AB} = \frac{K_{AB}}{K_{AB} + K_{AD}} = \frac{2.35}{2.35+2.35} = 0.5$$

$$DF_{AD} = \frac{K_{AD}}{K_{AB} + K_{AD}} = \frac{2.35}{2.35+2.35} = 0.5$$

$DF_{DA} = 0.5$

At joint B:

$DF_{BA} = 0.5$

$DF_{BC} = 0.5$

At joint C:

$$DF_{CB} = \frac{K_{CB}}{K_{CB} + K_{CD}} = \frac{2.35}{2.35+2.35} = 0.5$$

$$DF_{CD} = \frac{K_{CD}}{K_{CB} + K_{CD}} = \frac{2.35}{2.35+2.35} = 0.5$$

$DF_{DC} = 0.5$

(E) MOMENT DISTRIBUTION

$FEM_{AB} = 30.52kNm$

$FEM_{BA} = 30.52kNm$

$FEM_{BC} = 4.84kNm$

$FEM_{CB} = 5.33kNm$

$FEM_{AD} = FEM_{BC} = 4.84kNm$

$FEM_{DA} = FEM_{CB} = 5.33kNm$

$FEM_{CD} = 35.37kNm$

$FEM_{DC} = 35.37kNm$

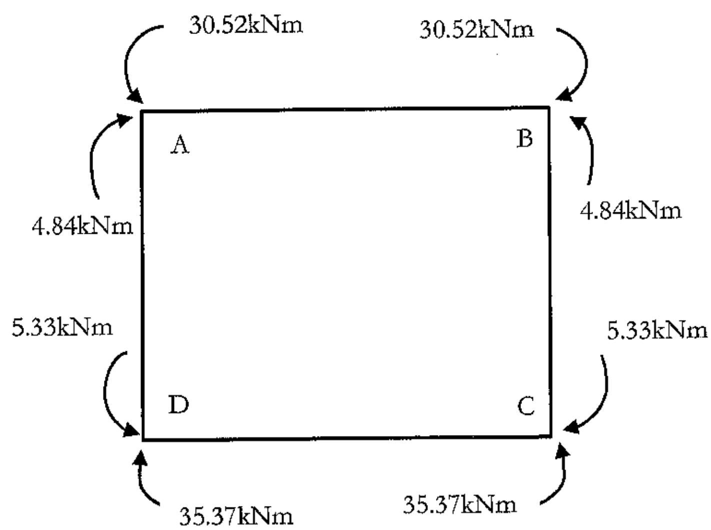

Figure A-6: Free body diagram

Table A-2: Moment distribution for total load on top slab, bottom slab and side walls

JOINT	A		B		C		D	
MEMBER	**AB**	**AD**	**BA**	**BC**	**CB**	**CD**	**DC**	**DA**
DF	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
FEM	-30.52	4.84	30.52	-4.84	5.33	-35.37	35.37	-5.33
DIST	12.84	12.84	-12.84	-12.84	15.02	15.02	-15.02	-15.02
C.O.	-6.42	-7.51	6.42	7.51	-6.42	-7.51	7.51	6.42
DIST.	6.965	6.965	-6.965	-6.965	6.965	6.965	-6.965	-6.965
C.O.	-3.48	-3.48	3.48	3.48	-3.48	-3.48	3.48	3.48
DIST.	3.48	3.48	-3.48	-3.48	3.48	3.48	-3.48	-3.48
C.O.	-1.74	-1.74	1.74	1.74	-1.74	-1.74	1.74	1.74
DIST.	1.74	1.74	-1.74	-1.74	1.74	1.74	-1.74	-1.74
C.O.	-0.87	-0.87	0.87	0.87	-0.87	-0.87	0.87	0.87
DIST.	0.87	0.87	-0.87	-0.87	0.87	0.87	-0.87	-0.87
FINAL	**-17.14**	**17.14**	**17.14**	**-17.14**	**20.90**	**-20.90**	**20.90**	**-20.90**

Table A-3: Mid-span moment (total loads only)

MEMBER	CALCULATIONS
$M_{AB} = M_{BA}$	45.78 - 17.14 = 28.64kNm
$M_{DC} = M_{CD}$	53.06 – 20.90 = 32.16kNm
$M_{AD} = M_{BC}$	7.61- $\frac{(17.14-20.90)}{2}$ = 11.41kNm

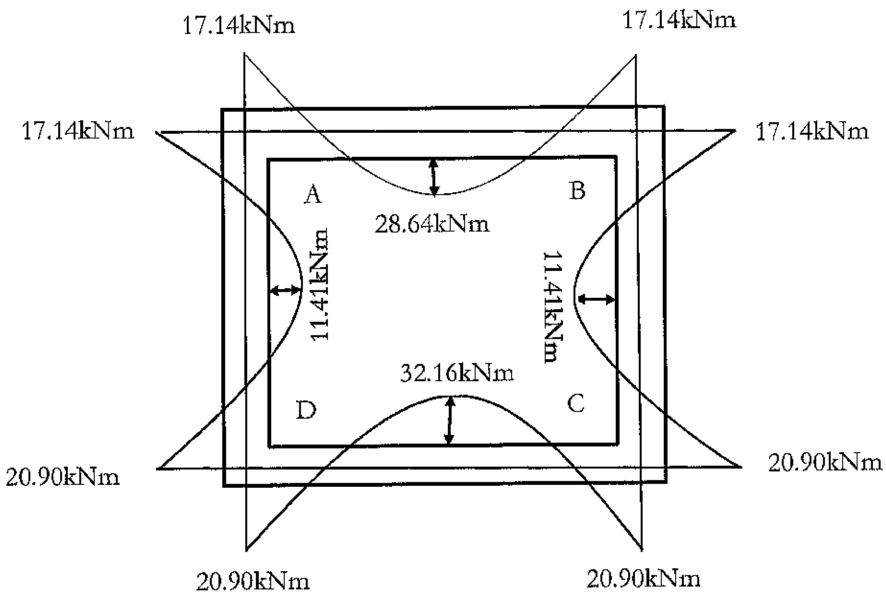

Figure A-7: Bending moment diagram

(F) DESIGN OF SECTION

Top slab:

$$\frac{M}{bh^2} = \frac{28.64 \times 10^6}{1000 \times 200^2} = 0.72$$

Minimum percentage of main steel = 0.4% bh

$A_{s,r}$ = 0.4% bh

$$= \frac{0.4 \times 1000 \times 200}{100}$$

$A_{s,r}$ = 800mm^2

Provide Y16@200mm $^c/_c$ spacing ($A_{s,p}$ = 1010mm^2)

For distribution reinforcement, minimum percentage of steel = 0.13% bh

$$A_{s,r} = \frac{0.13 \times 1000 \times 200}{100}$$

$A_{s,r}$ = 260mm^2

Provide Y12@300mm $^c/_c$ spacing ($A_{s,p}$ = 377mm^2)

Side wall:

$$\frac{M}{bh^2} = \frac{20.90 \times 10^6}{1000 \times 200^2} = 0.52$$

Minimum percentage of main steel = 0.4% bh

$A_{s,r}$ = 0.4% bh

$$= \frac{0.4 \times 1000 \times 200}{100}$$

$A_{s,r}$ = 800mm^2

Provide Y16@200mm $^c/_c$ spacing ($A_{s,p}$ = 1010mm^2)

For distribution reinforcement, minimum percentage of steel = 0.13% bh

$A_{s,r} = \frac{0.13 \times 1000 \times 200}{100}$

$A_{s,r} = 260mm^2$

Provide Y12@300mm $^c/_c$ spacing ($A_{s,p} = 377mm^2$)

<u>Bottom slab</u>:

$$\frac{M}{bh^2} = \frac{32.16 \times 10^6}{1000 \times 200^2} = 0.80$$

Minimum percentage of main steel = 0.4% bh

$A_{s,r} = 0.4\%$ bh

$= \frac{0.4 \times 1000 \times 200}{100}$

$A_{s,r} = 800mm^2$

Provide Y16@200mm $^c/_c$ spacing ($A_{s,p} = 1010mm^2$)

For distribution reinforcement, minimum percentage of steel = 0.13% bh

$A_{s,r} = \frac{0.13 \times 1000 \times 200}{100}$

$A_{s,r} = 260mm^2$

Provide Y12@300mm $^c/_c$ spacing ($A_{s,p} = 377mm^2$)

(G) DEFLECTION CHECK

Since all structural members (top slab, bottom slab and the side walls) have the same size and spacing of reinforcements, the deflection check covers all the members.

$$M_f = 0.55 + \frac{477 - F_s}{120\,[0.9 + \frac{M}{bd^2}]} \leq 2$$

Where $F_s = \frac{2}{3}\frac{A_{s,r}}{A_{s,p}} F_y$

$$= \frac{2}{3} \times \frac{800}{1010} \times 460$$

$F_s = 242.9$

$$M_f = 0.55 + \frac{477 - 242.9}{120\,[0.9 + \frac{28.60 \times 10^6}{1000 \times 152^2}]} \leq 2$$

$M_f = 1.46$

From table 3.9 (BS 8110), the basic span to effective depth ratio = 20mm

Limiting value = $M_f \times$ Sdf

= 1.46 × 20 = 29.2mm

Actual value $= \frac{span}{effective\ depth} = \frac{1700}{152}$

= 11.18mm

Since limiting value is greater than actual value (29.2 mm > 11.18mm), deflection is satisfied

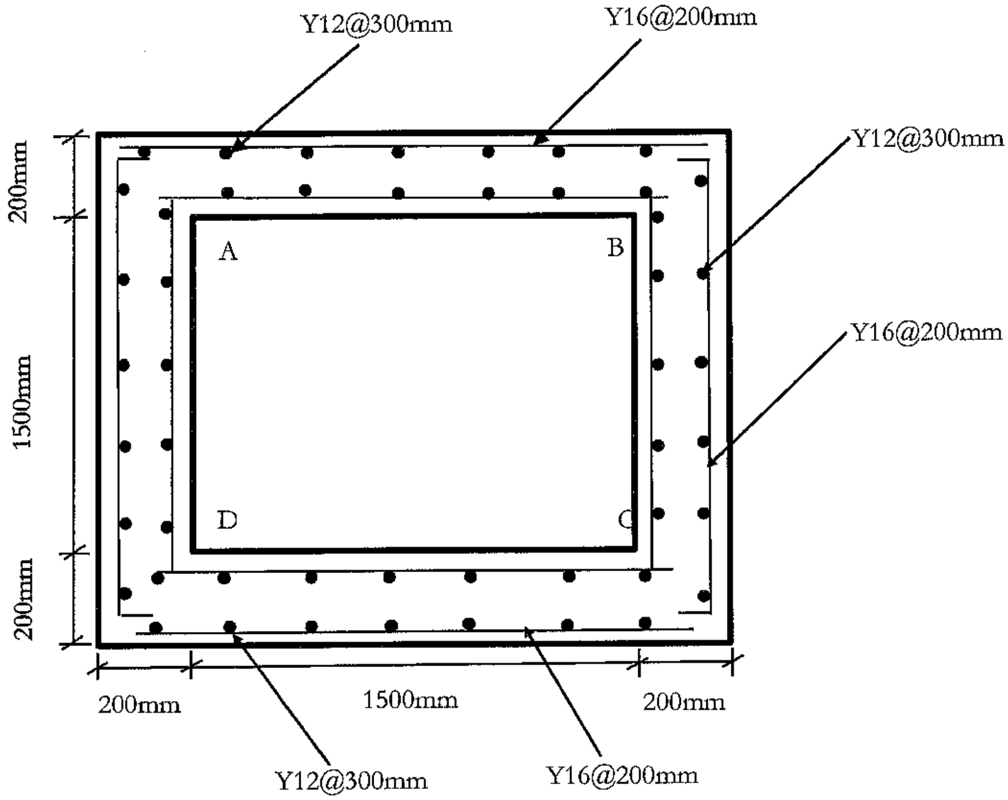

Figure A-8: Cross section of the box culvert

APPENDIX B

LINE DRAIN

Assumed bottom slab thickness = 200mm

Diameter of tension bar, ϕ = 16mm

Effective depth, d_{eff} = overall depth – cover – $\frac{\phi}{2}$

$= 200 - 40 - \frac{16}{2}$

d_{eff} = 152mm

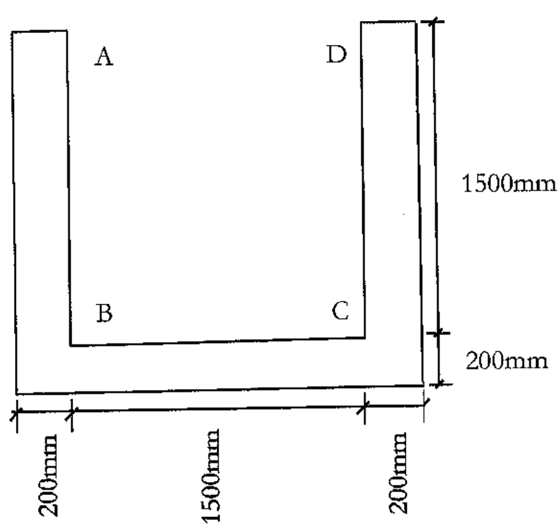

Figure B-1: Line drain

(A) LOAD CALCULATION

Side walls:

Assuming $\Theta = 30^0$

Coefficient of active pressure, $Ke = \frac{1-\sin\theta}{1+\sin\theta}$

$$Ke = \frac{1-\sin\theta}{1+\sin\theta}$$

$$Ke = 0.33$$

Pressure due to live load surcharge equivalent to 1.2m height of earth on both sides fills = 1.2 × 18 × 0.33 = 7.128kN/m^2

Pressure due to earth surcharge = 1.5 × 18 × 0.33 = 8.91kN/m^2

Pressure due to earth fill = 1.7 × 18 × 0.33 = 10.098kN/m^2

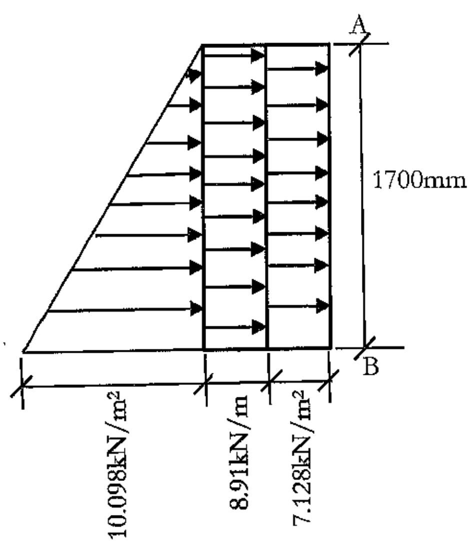

Figure B-2: Side wall loading

Bottom slab:

Wall weight = 2 (0.2 × 24 × 1.4)

= 13.44kN/m

Bottom slab weight = (0.2 × 24 × 1.4)

= 6.72kN/m

Total weight on bottom slab = 13.44 + 6.72

= 20.16kN/m

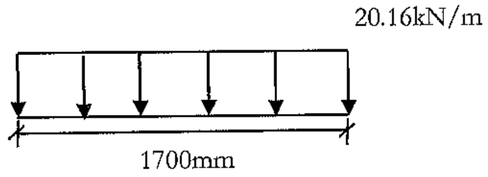

Figure B-3: Bottom slab loading

(B) SHEAR CALCULATION

<u>Side walls:</u>

$$V_{AB} = V_{DC} = \frac{(8.91+7.128)\times 1.7}{2} + \frac{10.098}{3} - \frac{(5.23-4.01)}{1.7}$$

$$= 13.63 + 3.366 - 1.22$$

$$V_{AB} = V_{DC} = 15.78kN$$

$$V_{BA} = V_{CD} = \frac{(8.91+7.128)\times 1.7}{2} + \frac{10.098}{3} + \frac{(5.23-4.01)}{1.7}$$

$$= 13.63 + 3.366 + 1.22$$

$$V_{BA} = V_{CD} = 21.58kN$$

$$V_{BC} = V_{CB} = \frac{WL}{2} = \frac{20.16 \times 1.7}{2}$$

$$V_{BC} = V_{CB} = 17.14Kn$$

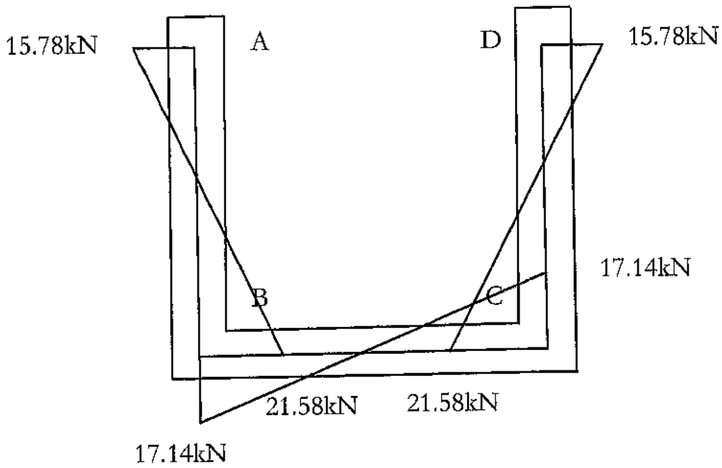

Figure B-4: Shear force diagram

(C) MOMENT CALCULATION

Side walls:

Fixed end moment at top due to dead load $= \frac{WL^2}{12} + \frac{WL^2}{30}$

$= \frac{8.91 \times 1.7^2}{12} + \frac{10.098 \times 1.7^2}{30}$

$= 2.15 + 0.97$

$= 3.12\text{kNm}$

Fixed end moment at top due to live load $= \frac{7.128 \times 1.7^2}{12}$

$= 1.72\text{kNm}$

Total FEM at top $= 3.12 + 1.72$

$= 4.84\text{kNm}$

Fixed end moment at base due to dead load $= \frac{8.91 \times 1.7^2}{12} + \frac{10.098 \times 1.7^2}{20}$

$= 2.15 + 1.46$

$= 3.16\text{kNm}$

Fixed end moment at base due to live load $= \frac{7.128 \times 1.7^2}{12}$

$= 1.72\text{kNm}$

Total FEM at base $= 3.61 + 1.72$

$= 5.33\text{kNm}$

Mid-span moment due to dead load $= \frac{WL^2}{8} + \frac{WL^2}{16}$

$= \frac{8.91 \times 1.7^2}{8} + \frac{10.098 \times 1.7^2}{16}$

$= 3.22 + 1.82$

$= 5.04\text{kNm}$

Mid-span moment due to live load $= \frac{WL^2}{8}$

$= \frac{7.128 \times 1.7^2}{8}$

$= 2.57\text{kNm}$

Total mid-span moment $= 5.04 + 2.57$

$= 7.61\text{kNm}$

Bottom slab:

Fixed end moment $= \frac{WL^2}{12} = \frac{20.16 \times 1.7^2}{12}$

$= 4.86\text{kNm}$

Mid-span moment $= \frac{WL^2}{8} = \frac{20.16 \times 1.7^2}{8}$

$= 7.28\text{kNm}$

(D) DISTRIBUTION FACTORS

Stiffness

$K_{AB} = \frac{4EI}{L} = \frac{4EI}{1.7} = 2.35EI$

$K_{BC} = \frac{4EI}{1.7} = 2.35EI$

$K_{CD} = 2.35EI$

At joint A:

$$DF_{AB} = \frac{K_{AB}}{K_{AB} + 0} = \frac{2.35}{2.35+0} = 1.0$$

At joint B:

$DF_{BA} = 0.5$

$DF_{BC} = 0.5$

At joint C:

$$DF_{CB} = \frac{K_{CB}}{K_{CB} + K_{CD}} = \frac{2.35}{2.35+2.35} = 0.5$$

$$DF_{CD} = \frac{K_{CD}}{K_{CB} + K_{CD}} = \frac{2.35}{2.35+2.35} = 0.5$$

At joint D:

$$DF_{DC} = \frac{K_{DC}}{K_{DC} + 0} = \frac{2.35}{2.35+0} = 1.0$$

(E) MOMENT DISTRIBUTION

$FEM_{AB} = 4.84$kNm

$FEM_{BA} = 5.33$kNm

$FEM_{BC} = 4.86$kNm

$FEM_{CB} = 4.86$kNm

$FEM_{CD} = 5.33$kNm

$FEM_{DC} = 4.84$kNm

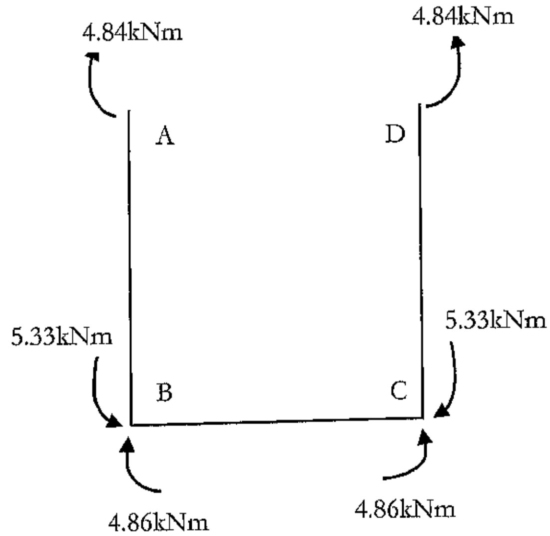

Figure B-5: Free body diagram

Table B-1: Moment distribution for total load on side walls and bottom slab

Joint	A		B		C	D
Member	AB	BA	BC	CB	CD	DC
DF	1.0	0.5	0.5	0.5	0.5	1.0
FEM	4.84	–5.33	4.86	–4.86	5.33	–4.84
DIST.	–0.47	0.235	0.235	–0.235	–0.235	0.47
C.O.	0.118	–0.235	–0.118	0.118	0.235	–0.118
DIST.	–0.353	0.177	0.177	0.177	0.177	0.353
C.O.	0.089	–0.177	–0.089	0.089	0.177	–0.089
DIST.	–0.266	0.133	0.133	–0.133	–0.133	0.266
C.O.	0.067	–0.133	–0.067	0.067	0.133	–0.067
DIST.	–0.02	0.1	0.1	–0.1	–0.1	0.02
FINAL	**4.01**	**–5.23**	**5.23**	**–5.23**	**5.23**	**–4.01**

Table B-2: Mid-span moments (total loads only)

Member	
$M_{AB} = M_{DC}$	$7.61 - \frac{(4.01+5.23)}{2} = 2.99$kNm
$M_{BC} = M_{CB}$	$7.28 - 5.23 = 2.05$kNm

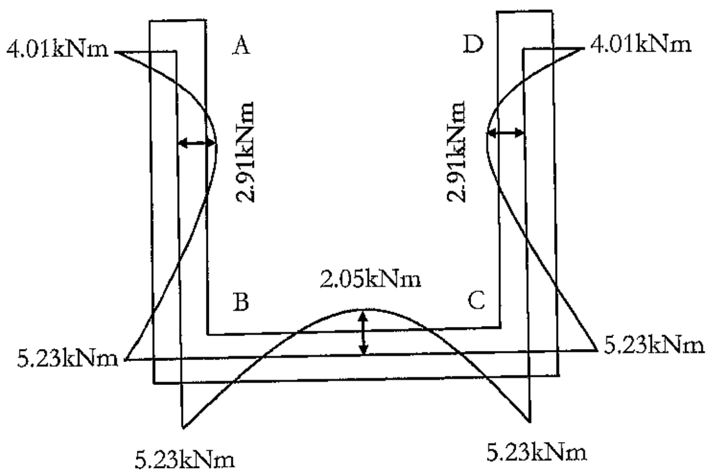

Figure B-6: Bending moment diagram

(F) DESIGN OF SECTION

<u>Side wall:</u>

$$\frac{M}{bh^2} = \frac{5.23 \times 10^6}{1000 \times 200^2} = 0.13$$

Minimum percentage of main steel = 0.4% bh

$A_{s,r}$ = 0.4% bh

$$= \frac{0.4 \times 1000 \times 200}{100}$$

$A_{s,r} = 800mm^2$

Provide Y16@200mm $^c/_c$ spacing ($A_{s,p} = 1010mm^2$)

For distribution reinforcement, minimum percentage of steel = 0.13% bh

$$A_{s,r} = \frac{0.13 \times 1000 \times 200}{100}$$

$A_{s,r} = 260mm^2$

Provide Y10@300mm $^c/_c$ spacing ($A_{s,p} = 262mm^2$)

Bottom slab:

$$\frac{M}{bh^2} = \frac{5.23 \times 10^6}{1000 \times 200^2} = 0.13$$

Minimum percentage of main steel = 0.4% bh

$A_{s,r}$ = 0.4% bh

$$= \frac{0.4 \times 1000 \times 200}{100}$$

$A_{s,r} = 800mm^2$

Provide Y16@200mm $^c/_c$ spacing ($A_{s,p} = 1010mm^2$)

For distribution reinforcement, minimum percentage of steel = 0.13% bh

$$A_{s,r} = \frac{0.13 \times 1000 \times 200}{100}$$

$A_{s,r} = 260mm^2$

Provide Y10@300mm $^c/_c$ spacing ($A_{s,p} = 262mm^2$)

(G) DEFLECTION CHECK

Since all structural members (top slab, bottom slab and the side walls) have the same size and spacing of reinforcements, the deflection check covers all the members.

$$M_f = 0.55 + \frac{477 - F_s}{120\,[0.9 + \frac{M}{bd^2}]} \leq 2$$

Where $F_s = \frac{2}{3}\frac{A_{s,r}}{A_{s,p}} F_y$

$$= \frac{2}{3} \times \frac{800}{1010} \times 460$$

$F_s = 242.9$

$$M_f = 0.55 + \frac{477-242.9}{120\,[0.9+\frac{28.60\times10^6}{1000\times152^2}]} \leq 2$$

$M_f = 1.46$

From table 3.9 (BS 8110), the basic span to effective depth ratio = 20mm

Limiting value = $M_f \times$ Sdf

$= 1.46 \times 20 = 29.2$mm

Actual value $= \frac{span}{effective\ depth} = \frac{1700}{152}$

$= 11.18$mm

Since limiting value is greater than actual value (29.2mm > 11.18mm), deflection is satisfied.

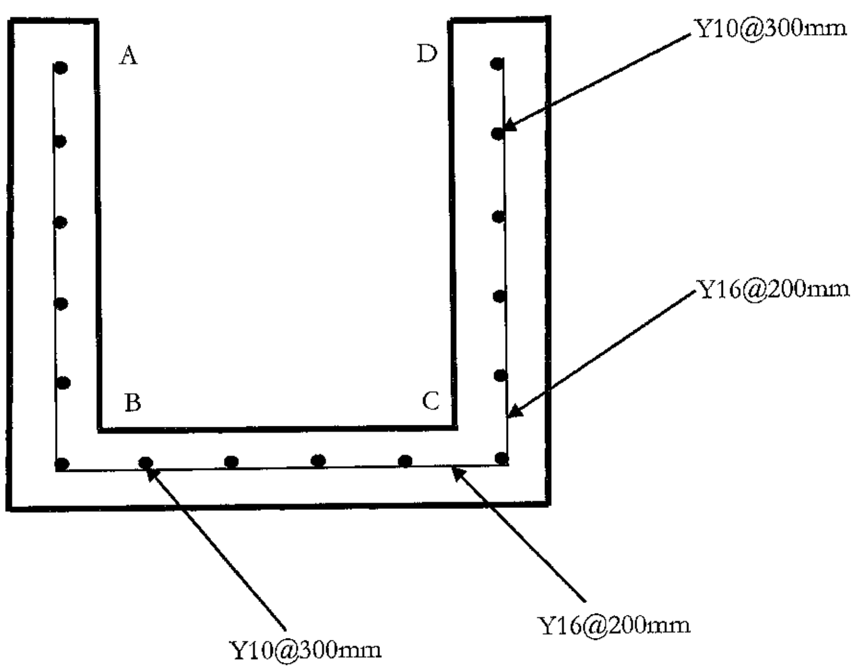

Figure B-7: Cross section of the line drain

SUMMARY

For Culvert

<u>Top Slab:</u>

Main bar = Y16@200mm $^{c}/_{c}$ spacing

Distribution bar = Y12@300mm $^{c}/_{c}$ spacing

<u>Side Walls:</u>

Main bar = Y16@200mm $^{c}/_{c}$ spacing

Distribution bar = Y12@300mm $^{c}/_{c}$ spacing

<u>Bottom Slab:</u>

Main bar = Y16@200mm $^{c}/_{c}$ spacing

Distribution bar = Y12@300mm $^{c}/_{c}$ spacing

For Line Drain

<u>Side Walls:</u>

Main bar = Y16@200mm $^{c}/_{c}$ spacing

Distribution bar = Y10@300mm $^{c}/_{c}$ spacing

<u>Bottom Slab:</u>

Main bar = Y16@200mm $^{c}/_{c}$ spacing

Distribution bar = Y10@300mm $^{c}/_{c}$ spacing

Table B-3: Values of Runoff Csoefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business:		**Lawns:**	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, avg, 2-7%	0.10-0.15
		Sandy soil, steep, 7%	0.15-0.20
		Heavy soil, flat, 2%	0.13-0.17
		Heavy soil, avg, 2-7%	0.18-0.22
		Heavy soil, steep, 7%	0.25-0.35
		Agriculture land:	
Residential:	0.30-0.50	Bare packed soil	
Single-family areas	0.40-0.60	*Smooth	0.30-0.60
Multi units, detached	0.60-0.75	*Rough	0.20-0.50
Multi units, attached	0.25-0.40	Cultivated rows	
Suburban		*Heavy soil, no crop	0.30-0.60
		*Heavy soil, with crop	0.20-0.50
		*Sandy soil, no crop	0.20-0.40
		*Sandy soil, with crop	0.10-0.25
		Pasture	
		*Heavy soil	0.15-0.45
		*Sandy soil	0.05-0.25
		Woodlands	0.05-0.25
Industrial:		**Streets:**	
Light areas	0.50-0.80	Asphaltic	0.70-0.95
Heavy areas	0.60-0.90	Concrete	0.80-0.95
		Brick	0.70-0.85
Parks, cemeteries	0.10-0.25	Unimproved areas	0.10-0.30
Playgrounds	0.20-0.35	Drives and walks	0.75-0.85
Railroad yard areas	0.20-0.40	Roofs	0.75-0.95

Sources: http://water.me.vccs.edu/courses/civ246/table2b.htm