ANALYSIS AND DESIGN OF DRAINAGE STRUCTURES FOR THE RECONSTRUCTION OF ENUGU-ONITSHA EXPRESSWAY

BY

ANUNOBI AUGUSTINE CHUKWUEBUKA

2017224065

A PROJECT SUBMITTED TO

THE DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

NNAMDI AZIKIWE UNIVERSITY AWKA

ANAMBRA STATE, NIGERIA.

IN PARTIAL FULFILMENT FOR AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE

MAY, 2023

CERTIFICATION PAGE

This is to certify that this project titled "Analyses and Design of Drainage Structures along Enugu-Onitsha Expressway Awka from Awkuzu Junction to Amawbia Flyover" was undertaken by Anunobi Augustine Chukwuebuka with registration number 2017224065 in the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University Awka, Anambra State.

---------------------------- Date -----------------------

Anunobi Augustine Chukwuebuka

(2017224065) / (Student)

APPROVAL PAGE

This is to certify that this project titled “Analysis and Design of Drainage Structure for the Reconstruction of Enugu-Onitsha Expressway Awka between Awkuzu Junction to Amawbia Flyover” is an authentic academic work undertaken by Anunobi Augustine Chukwuebuka with registration number 2017224065 in the department of Civil Engineering, Faculty of Engineering, Nnamdi Azikiwe University Awka, Anambra State, in partial fulfilment of the requirement for the award of Bachelor of Engineering (B. Eng.) Degree in Civil Engineering.

-- Date ---------------------------

REV. DR. CHIDOZIE MADU NWAKAIRE

Project Supervisor

-- Date --------------------------

Pr0f. Dr. C. A. EZEAGU

Head of Department

--- Date----------------------------

Prof. O. D. Onwuka

External Examiner

DEDICATION

I humbly dedicate my project to God Almighty, before whose feet I promise to prostrate all my efforts for his heavenly guidance, wisdom, protection, provisions, and understanding over the course of this project. To his glory, it was a wonderful success.

I also dedicate this work to my mother, Mrs. Franca Anunobi, and my other family members for their unwavering support and encouragement, especially at times when I have had moral lapses.

ACKNOWLEDGEMENT

I want to convey my sincere thankfulness to the Almighty God for his unfailing favor during my academic career.

A project of this size is challenging to complete without the assistance of significant persons. In fact, without their significant contributions, this information would not have come to pass.

My family, Mrs. Franca Anunobi, my siblings, uncles, and aunts deserve my gratitude for their assistance. They truly are the best, without a doubt.

The study and design of this project would not have been possible without the patience, persistent advice, support, encouragement, and availability of Rev. Dr. Chidozie Nwakaire, my supervisor. May you continue to get many blessings from the good Lord who you serve in his vineyard.

My admiration and sincere gratitude are extended to my department's head, engineer Dr. C.A. Ezeagu, as well as to my immediate past department head, professor C.A. Chidolue. Engr. Prof. (Mr.) C. M. Nwaiwu, Engr. Prof. (Mrs.) Nwajuaku, Engr. (Mrs.) Nwajuaku, Engr. Mrs. Nkechi Ezema (my course adviser), Engr. Obinna Ubani (CEO Structville Integrated Service), Engr. Mezie, Engr. Omaliko, Engr. F. C. Uzodimma. Thanks the entire department's academic and non-academic personnel for the knowledge they imprinted on me and helped me apply to my degree program of study.

I won't be able to fully list all the people who have supported me in any manner due to time and space constraints, but I sincerely pray that God would bless them all and give them the opportunity to properly beautify their lives in the name of Jesus, Amen.

ABSTRACT

The deterioration of pavement is further accelerated by poor drainage, which raises the cost of annual repair. In this project, efficient drainage system were designed and analyzed in an effort to reconstruct the frequently flooded Enugu-Onitsha express road. (From Awkuzu to Amobia flyover junction). In-depth knowledge about the origins and effects of a faulty drainage system was sought after by this project investigation. Primary data and secondary data are the methods utilized to evaluate the current drainage system of the roads under study. While conducting a field study, primary data was gathered by direct measurement, while secondary data came from the Anambra State ministry of works. According to observations made on the ground, the drainage structures experienced clogs caused by the dumping of trash, insufficient inlets and outlet channels, side wall failure, and bed erosion. The roadways under investigation suffer tremendous strain and damage as a result of this dire drainage issue. The peak discharge was calculated using the logical formula. In order to calculate the design discharge for the drain and culvert, a return period of ten years was chosen. The intensity duration frequency (IDF) curve for Awka was used to determine the required rainfall intensities. Side drains and box culverts were planned using Microsoft Excel software in compliance with BS 8110 and BS 5400 regulations. The channels were typically constructed based on two scenarios: an empty drainage system with earth pressure acting, and a filled drainage system with water pressure acting. In contrast to the design moments calculated for the box culverts, which were 13.69kNm, 22.29kNm, and 99.20kNm for the support, span, and walls correspondingly, the design moments for the side drains were 5.48kNm and 5.38kNm for the walls and base, respectively. The draft final estimated total cost for the building of the proposed drainage and culvert structures was determined to be N210,750,012 in the Bill of Engineering Measurement and Evaluation (BEME) for the project. Autocad software was used to create the roadway layout, drainage structural elements, bar bending schedule, and more. The Federal Government was advised to immediately begin the road's renovation in order to improve the situation for local residents and commuters and to give the state capital's most crucial thoroughfare a facelift.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Road is an indispensable ingredient of development in any society. In built up areas, network of roads are constructed to support human and vehicle traffic.

In complements, drainage facilities are provided to ensure timely disposal of sewages and surface water run-off generated from expansive impermeable surfaces. The convergence of such a drain is facilitated if the ground surface or its inverts has sufficient slope. An effective drainage system has the capacity to remove overland flow soon after the rainfall.

Provision of sufficient drainage is an important factor in the location and geometric design of highways. Drainage facilities on any highway or street should adequately provide for the flow of water away from the surface of the pavement to properly designed channels. Inadequate drainage will eventually result in serious damage to the highway structure. In addition, traffic may be slowed by accumulated water on the pavement, and accidents may occur as a result of hydroplaning and loss of visibility from splash and spray. The importance of enough drainage is recognized in the amount of highway construction funds allocated to drainage facilities. About 25 percent of highway construction funds are spent for erosion control and drainage structures, such as culverts, bridges, channels, and ditches. The highway engineer is concerned primarily with two sources of water. The first surface water, is that which occurs as rain. Some of this is absorbed into the soil, and the remainder remains on the surface of the ground and should be removed from the highway pavement. Drainage for this source of water is referred to as surface drainage. The second source, ground water, is that which flows in underground streams. This may become important in highway cuts or at locations where a high water table exists near the pavement structure. Drainage for this source is referred to as subsurface drainage.

Pavement may get water broadly from surface and subsurface sources. Surface water sources are rainfall, snow melting, etc. A major part of this water flows over the surface to the nearby channel and is discharged. Therefore, the pavement must have longitudinal and transverse slopes in order to carry this water to the nearby channel under gravity. The discharge channel must be capable of efficiently discharging the surface water.

The objective of drainage system is to prevent onsite water standing on the surface and convey the offsite storm runoff from one side of the roadway to the other. To carry out the offsite drainage, drainage channel such as Culvert are adopted. Culverts are closed conduits in which the top of the structure is covered by embankment (ERA Drainage Design Manual, 2013).

According to Kolade, A. (2022), he states that a complete design of a road pavement drainage system involves hydraulic design, geotechnical design and structural design.

Hydraulic design involves the proper sizing of the drain to ensure that the design flood is properly discharged.

Geotechnical design involves the capacity of the supporting soil to carry the weight of the channel and the water. It also involves the verification of the soil structures.

Structural design involves the selection of the proper material, thickness and reinforcement to withstand the pressures and forces exerted by the soil and water.

As the water can cause a serious impact on both the road access and its strength, an efficient drainage system is the most important part of the road construction and maintenance works.

Drainage is the process of interception and removal of water from over and under the proximity of the road surface. Drainage can be surface (where water is conveyed on the road surface and drainage channel) or subsurface (water flows the underneath the pavement structure).

Surface and Subsurface drainage of roads critically affects their structural integrity, life, and safety to the users and it's thus important during highway design and construction. Road design therefore have to provide effective and efficient means for removal of water, which calls for the purpose for road drainage designs.

Drainage facilities are required to protect the road against damage from surface and subsurface water. Hydroplaning, structural integrity and life of a pavement are some of the dangerous conditions which compromises the traffic safety due to poor drainage. Drainage system combines various natural and man-made facilities like dishes, pipes, culvert and curbs to convey this water safely (US Forest Service, 2014)

Various roads in Nigeria have poor drainage facilities, with surface runoff not catered for properly. For the proper integrity of the road structure to be ensured, rainfall and surface runoff from the road have to be removed quickly. Drainage design must allow for storm water to be transported away from the road in the cheapest, simplest and most efficient way without damaging the road structure.

Good drainage needs to be taken into consideration at the early design in order to secure a long life for the road. With a well design drainage system, future rehabilitation and maintenance work can be considerably reduced and thus limit the cost of keeping the road in good condition.

Ensuring good drainage begins when selecting the road alignment. A center line that avoids poorly drained areas, large runoff and unnecessary stream crossings will reduce the drainage problems. Provision of sufficient drainage is an important factor in the location and geometric design of drainage of highways. Drainage facility on any highway or street should adequately provide for the flow of water away from the surface of the pavement to properly designed channels. In additions, traffic maybe slowed by accumulated water on the floor and accident may occur as a result of hydroplaning and loss of visibility from squish and sprig. The importance of enough drainage is recognized in the amount of highway construction dollars allocated to drainage facilities. About 25 percent of highway construction dollars are spent for erosion control and drainage structures, such as culverts, bridges, channels, and ditches (Wyatt, 2000).

Surface drainage encompasses all means by which surface water is removed from the pavement and right of way of the highway or street. A properly designed highway surface drainage system should effectively intercept all surface and watershed runoff and direct this water into adequately designed channels and gutter for eventual discharged into the natural waterways. Water seeping through cracks in the highway riding surface and shoulder areas into the underlying layers of the pavement may result in serious damage of the highway pavement. The major source of water for this type of intrusion is surface runoff. An adequate designed surface drainage system will therefore minimize this type of damage. The surface drainage system for rural highways should include sufficient transverse and longitudinal on both the pavement and shoulder to ensure positive runoff and longitudinal channel (ditches), culvert to provide for the discharge of the surface water to the natural waterways. Storm drains and inlets are also provided on the median of the divided highways on the rural areas. In urban areas, the surface drainage system also includes enough longitudinal and transverse slope, but the longitudinal drains are usually underground pipe drains designed to carry both surface runoff and ground water. Curbs and gutters also may be used in urban and rural areas to control street runoff, although they are more frequently used in urban areas (Wyatt, 2000).

The ancient Romans who started building the 50,000 mile imperial Roman road network in 312 B.C knew of the damaging effects of water and tried to keep their roads above the level of the surroundings terrain. In addition to constructing these roads with thick section, they often provided a sand layer on top of the sub-grade. The durability of those highways is provided by the fact many of them still exist (Muhammad, 2014).

Drainage facilities are required to protect the road against damage from surface and sub-surface water. Traffic safety is also important as poor as poor drainage can result in dangerous conditions like hydroplaning. Poor drainage can also compromise the structural integrity and live of the pavement. Drainage system combine various natural and a man-made facility e.g. ditches, pipes, culverts, curbs to convey this water safely (US Forest Service, 1979).

The drainage structure under review here is the **box culvert**. Culvert can be defined as a structure used to convey surface runoff through embankment. A culvert is a small opening of less than six meters (6m) provided to allow the flow of water pass through the embankment and follow the natural channel. Since culvert pass through the earthen embankment, subjected to some traffic load as the load carries, the structural elements are required to be designed to withstand maximum bending moments and shear forces.

Culvert is a hydraulic structure that allows water to flow under a road, railway, trail or similar obstruction from one side to the other side. Typically embedded so as to be surrounded by soil. Culvert can be constructed from a variety of materials including cast-in-situ or precast concrete. Precast reinforced concrete (RC) culvert are very common and usually constructed as single or multi-cell culverts. Precast reinforced concrete (RC) culvert offer advantages such as enhanced quality control, use of higher strength concrete, relative low cost due to mass production and shorter installation time.

Culverts are commonly used both as cross-drain for ditch relief and to pass water under a road at natural drainage and stream crossing. A culvert maybe bridge-like structure design to allow vehicle or pedestrian traffic to cross over the waterway while allowing adequate passage for water (Ola 2018). Culverts comes in many sizes and shapes including round, elliptical and box-like construction. The type and shape selection are based on a number of factors including requirements for hydraulic performance, roadway embankment height, surface elevation and limitation of upstream water.

The structural analysis and design of box culvert is therefore the determination of the stresses and strain developed by the culvert when loaded and providing the appropriate reinforcement members to suit this stresses and strains. The standard element are required to be designed so as to withstand maximum bending moment and shear forces with relevant code required to be referred.

The road under discussion is the Enugu-Onitsha express road. It is an existing road with some level of ongoing maintenance, but it was noticed that the existing drainage does not carter for the design of the road, as such water flow over the road whenever there is a heavy downpour. Hence there is need for a compressive drainage facility. This study therefore present the structural analysis and design for a single and triple box culverts along the above mentioned road using Euro code 2.

1.2 Statement of Problem

The existing road and the current drainage system along the Enugu-Onitsha express road is inadequate and showing signs of failure caused mainly by poor drainage system. The existing drainage channels are narrow and shallow, and unable to accommodate the volume of water that flows during heavy rainfall, leading to flood that disrupt traffic and cause damage to property. In addition, the channel are often blocked by debris and waste, which further hinders the flow of water thereby leading to the flooding of the road pavement.

The Enugu-Onitsha express road have been experiencing huge congestion and water logging during the rainy season for the past few years which has cause serious problems. The logged water become polluted with solid wastes, sands and contaminants leading to unhealthy environment and spreading serious diseases. The road was also made almost inaccessible during the period of heavy downpour due to menace.

Poor drainage system has an immediate negative impact on the road performance, the redesign of this drainage system was found necessary so as to ensure sustainability of the road in question.

Designing this system will reduce the cost of maintenance, easy access of users from Enugu to Onitsha and other immediate communities within the area since the road will be in good condition.

1.3 Aim and Objective of the Study

The aim of this project is to design an effective and efficient, easy to maintain drainage system along Enugu-Onitsha express road.

The Objective of the Study include:

1. To reconnaissance study of the area
2. To evaluate the current road drainage design system
3. To develop better design for drainage system using results or information obtained.
4. To prepare a Structural Detailing and Bar Bending Schedule for the design outputs.
5. To prepare a Bill of Engineering Measurement and Evaluation (BEME) in order to estimate the grand total cost of the project.
6. To make relevant recommendations based on the outcome of the design and research.

1.4 Scope of Study.

This study is essentially centered at improving the design life condition of a single and triple box culvert along Enugu-Onitsha express road through an accurate and efficient structural analysis, design and detailing. This process involves estimation of load (dead and live), generation of internal stresses (bending moment and shear forces), design and specification of sizes, types, numbers and spacing of reinforcement steel to be provided.

1.5 Significance of the Study

This study would answer the questions of the users and also be utilized by the Nigerians government (federal road) as to the solution of the rapid failure of the existing roads. It will benefit the following governmental agencies like the ministry of environment, the ministry of health and information and ministry of transportation (FRSC).

It will be beneficial for these ministries in the area of policy formation for the user (educating the public) and formulating laws that will promote human health, safety and protect the environment (erosion).

This study is necessary to preserve and promote the public health and welfare, for flood protection, to reduce water pollution, to improve economic development of any region.

Non-governmental agencies organization (NGOs) around the area will also benefit. This study will guide them in the distribution and transportation of produced materials, goods and citizens without any or less severe casualties while plying the said road.

Another key relevance of this study is that it will help the media houses and others who are charged with the responsibilities of creating awareness.

The proposed redesign of the drainage system will also provide the following benefits:

Reduced the risk of flooding: The widened and deepened drainage channels, together to the additional channel will significantly reduce the risk of flooding along the road.

Improve safety for road users: The reduced risk of flooding will improve the safety for road users, including drivers, pedestrians, and cyclists.

Improve aesthetics: The redesigned drainage system will be more aesthetically pleasing than the current system, as it will be better integrated into the landscape and designed to be more visually appealing.

Reduced damage of property: The redesign will significantly reduce the risk of damage to property along the road, such as shop and house.

CHAPTER TWO

LITERATURE REVIEW

2.1 OVERVIEW OF ROAD DRAINAGE SYSTEM

Drainage structures are constructed to carry traffic over natural waterways that flow below the right of way of the highway. These structures also provide for the flow of water below the highway, along the natural channel, without significant alteration or disturbance to its normal course. One of the main concerns of the highway engineers to provide an adequate size structure, such that the waterway opening is sufficiently large to discharge the expected flow of water. Inadequately sized structures can result in water impounding, which may lead to failure of the adjacent sections of the highway due to embankments being submerged in water for long periods. The two general categories of drainage structures are major and minor. Major structures are those with clear spans greater than 20 ft., whereas minor structures are those with clear spans of 20 ft. or less. Major structures are usually large bridges, although multiple-span culverts also may be included in this class. Minor structures include small bridges and culverts.

Highway drainage system is the process of interception and removal of water from over, under and in the vicinity of the pavement.

Highway drainage is the process of removing and controlling excess surface and subsurface water into the right of way. This include interception and diversion of water from the road surface and subgrade. The installation of suitable surface and subsurface drainage system is an essential part of highway design and construction. Good highway drainage is important for road safety. Water left standing on roads can cause maintenance problems, as it can soften the ground under the road making the road surface break up and as well lead to accident from the road users (Amit, 2016).

Muhammad, (2014) studied highway drainage system and stated that highway is importance for removing water from the road surface, preventing ingress of water into the pavement, passing water across the road, either over or under and preventing scour and/ or washout of the pavement, shoulder batter slopes, water courses and drainage structures. He identifies types of drainage on the highway to include curb and gullies, surface water channel, combined shelter filter drain

(French drain), over-the-edge drainage, drainage channel lock, combined curb and drainage units, linear drainage channel, fin and narrow filter drain (sub-surface drainage) and edge drain for porous plate.

According to Civil Engineering Dictionary (2014), highway drainage includes collecting, transporting and depositing of surface/subsurface water originating on or near highway right of way or flowing in streams crossing bordering that right of way. This is important because of water damages highway structures in many ways. The water which are dangerous for highway are: Rainwater: Causes erosion on surface or may seep downward and damage pavement (surface drain), Groundwater: May rise by capillary action and damage pavement (sub-surface damage) and Water body: May cross a road (river/stream) and may damage road (cross drainage words).

In a research on drainage on road by Singh, Navpreet and Nitin (2014), a well design and well maintained road drainage is important in other to: minimize the environmental impact of the road runoff on the receiving water environment, ensures the speedy removal of surface water to enhance safety and infrastructure. Water in the pavement system can lead to moisture damage, modulus reduction and loss of strength. In other to prevent such damages to a pavement, it is essential to provide proper drainage to the road. They maintained that the presence of water in a highway layer reduces the bearing capacity of the road, and in doing so it also reduces the structure′s lifetime. Highway drainage is used to clear surface water from the highway. Roads need to be well drained to stopped to flooding; even surface water can cause problems with ice in the winter. Water left standing on roads can also cause maintenance problems, as it can soften the ground under a road making the road surface to break up.

Highway drainage is one of the most important factors of road design and construction. If every other aspect of highway design and construction is done well but drainage is poorly constructed, the road will fail rapidly because of ingress of water into the pavement and its base.

The damaging effect of water in the pavement can be controlled by keeping water out of place where it can cause damage or by constructing a drainage system where the water can be rapidly and safely channeled to.

Improper drainage of the road can lead to;

1. Hydroplaning

2. Loss of the strength of the pavement materials
3. Mud pumping in rigid pavement
4. Stripping of the bituminous surface in flexible pavement
5. Quick deterioration after construction

2.2 Types of drainage

There are basically two types of drainage applied to highway that is; **surface drainage** and **subsurface drainage**.

Subsurface drainage is concerned with the interception and removal of water from within the pavement. Some of the sources of subsurface water include infiltration through the cracked surface, seepage from the side of the pavements, capillary rise from lower layers with high water table to mention but a few.

The subsurface drainage system must be an integral part of the total drainage system, since the subsurface drains must operate in consonance with the surface drainage system to obtain an efficient overall drainage system. The design of subsurface drainage should be carried out as an integral part of the complete design of the highway, since inadequate subsurface drainage also may have detrimental effects on the stability of slopes and pavement performance. However, certain design elements of the highway such as geometry and material properties are required for the design of the subdrainage system. Thus, the procedure usually adopted for subdrainage design is first to determine the geometric and structural requirements of the highway based on standard design practice, and then to subject these to a subsurface drainage analysis to determine the subdrainage requirements. In some cases, the subdrainage requirements determined from this analysis will require some changes in the original design. It's extremely difficult, if not impossible, to develop standard solutions for solving subdrainage problems because of the many different situations that engineers come across in practice. Therefore, basic methods of analysis are given that can be used as tools to identify solutions for subdrainage problems. The experience gained from field and laboratory observations for a particular location, coupled with good engineering judgment, should always be used in conjunction with the design tools provided. Before presenting the design tools, discussions of the effects on the highway of an inadequate subdrainage system and the different subdrainage systems are first presented.

Some of the measures of effecting subsurface drainage include application of side slope on the road surface, installing of drainage beds in the pavement and use of transverse drain.

Surface drainage encompasses all means by which surface water is removed from the pavement and right of way of the highway or street. A properly designed highway surface drainage system should effectively intercept all surface and watershed runoff and direct this water into adequately designed channels and gutters for eventual discharge into the natural waterways. Water seeping through cracks in the highway riding surface and shoulder areas into underlying layers of the pavement may result in serious damage to the highway pavement. The major source of water for this type of intrusion is surface runoff. An adequately designed surface drainage system will therefore minimize this type of damage. The surface drainage system for rural highways should include sufficient transverse and longitudinal slopes on both the pavement and shoulder to ensure positive runoff and longitudinal channels (ditches), culverts, and bridges to provide for the discharge of the surface water to the natural water ways.

Storm drains and inlets are also provided on the median of divided highways in rural areas. In urban areas, the surface drainage system also includes enough longitudinal and transverse slopes, but the longitudinal drains are usually under-ground pipe drains designed to carry both surface runoff and ground water. Curbs and gutters also may be used in urban and rural areas to control street runoff, although they are more frequently used in urban areas.

Surface drainage deals with arrangements for quickly and effectively leading away the water that collects on the surface of the pavements, shoulders, slopes of embankments, cuts and the land adjoining the highway.

The water collected is led into natural channels or artificial channels so that it does not interfere with the proper functioning of any part of the highway.

The main source of surface water in most places is precipitation in form of rain. When precipitation occurs in an area, so of the water infiltrates into the ground while a considerable amount remains on the top of the surface runoff.

Surface drainage must be provided to drive the precipitation away from the pavement structure. This can be done through use of shoulders, ditches and culverts.

Surface drainage design includes the prediction of runoff and infiltration as well as open channel analysis and culverts design for the movement of surface water to the convenient location or natural occurring paths. So, the surface drainage study can be conveniently divided into two parts namely:

Hydrological study- which is concerned with the determination of water reaching the inlet of drainage ditch or culverts.

Hydraulic study- it is concerned with the design of the facilities needed to handle the water arriving at the inlet.

2.3 Hydrological study

Hydrology is the science that deals with the characteristics and distribution of water in the atmosphere, on the earth's surface, and in the ground. The basic phenomenon in hydrology is the cycle that consists of precipitation occurring onto the ground in the form of water, snow, hail, and so forth and returning to the atmosphere in the form of vapor. It is customary in hydrology to refer to all forms of precipitation as rainfall, with precipitation usually measured in terms of the equivalent depth of water that is accumulated on the ground surface.

This deals mainly with the precipitation and runoff in the area of interest. When rainfall, which is the major source of surface water, falls onto an area, some of the water infiltrates into the soil while the remaining portion either evaporates or runoff.

The portion that remains as runoff is one of the most important element needed during the design of surface drainage facilities.

2.4 Determination of runoff

The rational method is one of the most common methods used to calculate small-drainage peak flows of less than 200 acres. This approach is the most accurate for small-drainage runoff estimates with lots of impervious area. This is because the rational method needs the duration of the storm to be at least equal to the time of concentration. Time of concentration means the time required to flow the runoff from the farthest point of the catchment to the desired outlet.

Runoff at a particular point is determined with respect to a given catchment area depends on a number of factor such as: type and condition of the soil in the catchment, length and steepness of the slopes and the development of the area, kind and extent of cultivation or vegetation, etc.

For the calculation of runoff, the following formula known as the rational formula is used

$$Q = 0.028CIA$$

Where Q is maximum runoff in m³ per sec

C is a constant depending upon the nature of the surface

I is the critical intensity of storm in mm per hour occurring during the time of concentration

A is the catchment area in hectares

2.5 Determining/Estimating the design flow

1. Estimation of watershed area A_d from a topographic map.
2. Obtain cover factor C from table. It may be necessary to obtain the weighted average in the drainage area, by weighing each C value with the proportion of the drainage area it covers.
3. Hydraulic length L_h and slope G is obtained from the site map. It may be necessary to determine the different L_h and G values for different cover factors, C.
4. Obtain the C_g factor for each homogenous portion along the hydraulic length.
5. Determination of the concentration time, $t_c = C_g L_h^{0.5}$ for each C_g value, and aggregate the values.
6. Use the IDF graphs to obtain intensity I in mm/hr for different return periods and concentration times.
7. Peak rate of runoff. $q_p = A_d C_i$

2.6 Hydraulic design

This involves the design of those facilities to be use for directing water away from the road surface/pavement where natural channels are not available to convey the runoff from a given catchment safely across/along the road pavement. Those facilities include: Kerbs inlet, sides drain in the cut section, longitudinal drains along the edge of the pavement, catch water drains and so on.

These design involves the selection of a suitable dimensions and the shape for the drainage facility to be use for the given project.

Manning′s equation are used mostly during the hydraulic design and is given by

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

Q – Discharge (ft^3/s)

V – Velocity (ft/s)

S – Slope, A – area (ft^2)

P – Wetted perimeter (ft)

n - Manning′s constant

Geometric dimensions are used to calculate the area, wetted perimeter, hydraulic radius and channel top width for standard channel cross sections.

2.7 Culvert design

For the design of each culvert, the following procedure is to be adopted.

75% of the quantity of flow is to be use for the design, that is, when the velocity is maximum in the culvert.

$$Q_d = 0.75Q$$

Using manning equation and a suitable slope for each section

Take note: ensure that the slope chosen is sufficient for flow velocity while avoiding scouring, silting and sedimentation on the top of the base of the culvert.

The minimum diameter of a pipe under the road should be 600mm or its equivalent in corrugated metal pipe arches. The minimum size may be decreased to 450mm diameter whenever the culvert are laid on grade not producing self-scouring velocities and where maintenance is not likely to be a problem.

Similarly, the precast concrete portal type culvert under a road should have a minimum size of 750mm x 450mm. This may be reduced to 450mm x 300mm wherever self-scouring of velocities through the culvert can be achieved, resulting in a maintenance fee structure.

For cross culvert where the cross slopes are not less than 3% and also for side-drains or drive, it is recommended that 750mm minimum size should be applied.

V = $R\frac{2}{3}S\frac{1}{2}n$

Assuming full flow,

$R = A/P$

$R = (d^2/4)/2\pi d$

$= d/8\pi$

Note:

During the design of open channel**,** it is important to also calculate the critical depth in other to determine if the flow in the channel will be supercritical or subcritical.

If the flow is supercritical, the depth of flow at any point is influenced by control upstream, usually critical depth.

d = V/g

In a subcritical flow, it is very easy to handle the flow through the channel transition because the flows are calm and wave action are minimal. The depth at any flow is also influenced by a downstream control which may be either the critical depth or the lager downstream channel or the water surface elevation in the pond.

2.8 Open Drainage Channels

An open drainage channel is a waterway, canal or conduit in which a liquid flows with a free surface. This are used to transport water under the influence of gravity, their top are always open and can be manmade or natural. This open channel flow is assumed to occur in closed conduit like culvert if they are partially full.

2.8.1 Types of open drainage channels

1. Roadway open channel flow
2. Roadway channels
3. Chutes
4. Gutters
5. Toe of slope channels
6. Intercepting channels
7. Median swales

2.8.2 Factors to be consider during selection of channel type

1. The plans on future expansion of the road.
2. The site constraint within pavement environment, examples: width restrictions, existing service.
3. Landscaping of highway environment.
4. The requirement for maintenance which include cost associated with maintenance, safety of maintenance staff.
5. Existing and likely future channel conditions of immediate upstream and downstream as pertain to the volume of discharge.

2.9 Culverts

A culvert is a transverse and totally enclosed drain under a road. They can either be prefabricated or constructed in place. They are constructed in many shapes: the pipe culvert and a box culvert. Other form like the oval/elliptical are available but are now becoming obsolete. The pipe culvert is precast while the box culvert is either precast or cast in-situ. They are formed from variety of materials depending on structural strength, cost, and durability. Most common are concrete, corrugated steel and aluminum.

Their selections are based on

1. Channel characteristics
2. Hydraulic performance

3. Construction process
4. Maintenance

A culvert is defined as standard specifications as any structure whether made up of single and multiple cell construction with a clear span 6m. Box Culvert which has gotten its name due to its shape, orientation and looks like a hollow rectangular box with two slab and vertical walls which connects monolithically. They are easy to design and easy to construct economically. Box culvert is designed to carry all the load that comes from the top slab and transfer them with the help of the vertical walls to the bottom slab which rest generally where the bearing capacity of the soil is low. Box culvert are generally found in three locations, the first is at the bottom of depressions where no natural Water course exist, second is where natural stream intersect the roadway and the last is at locations required for passing surface water carried in the ditches beneath roadways and driveways to adjacent property. There are general problem which are related with box culvert and they include serviceability and strength, abrasion and deterioration of concrete. For masonry culverts, the major causes for this problem is due to sedimentation and blockages by debris. A culvert can either be rigid (made with concrete) or flexible (made with steel). A rigid culvert is constructed to withstand bending moment whereas the flexible culvert are not.

2.9.1 Classification of culverts

Culverts are of different types and mostly depends on its shape and they are;

1. Box Culverts
2. Pipe Culverts
3. Pipe Arch Culverts
4. Arch Culverts
5. RCC Solid Culverts

1. Box Culvert.

Box Culvert is the arrangement made to cross an obstacle in the form of a stream, a river, or a road without closing the way beneath (Sagar and Roshan, 2019). Box culvert is always in a rectangular shape and the material used for its constructions are sand, cement, reinforcement, gravel etc. this type of culvert is use to drain the rainwater, river water and storm water under the road embankment. Rectangular cross-section culvert are easily adaptable to a wide range of site conditions including sites that requires low profile structures. Due to its flat side and top, rectangular shapes are not as structurally efficient as other culvert shapes. In addition, box section have an integral floor and it's made of concrete and especially Reinforced Concrete (RCC). The most challenging part in constructing a box culvert is that a dry surface is required during its installation. However, due to the strength of concrete floor, water direction can be changed when a large amount of water is expected. This fixture makes the box culvert one of the most commonly type of culvert. Some of its advantages include: simplicity of construction, it reduces substantial amount of pressure on the soil through its bottom slab, due to its rigidity, monolithic action and also requires no separate foundation, it is most preferable because its more economical.

2. Pipe Culvert.

Pipe culvert generally uses for drainage system looks round in shape. Their shape varies from circular, elliptical, and pipe arch. Their shape depends on the site conditions and constraints. The diameter size of the pipe culvert is between 1m to 6m. pipe culvert maybe a single or multiple pipe. A single pipe culvert with larger diameter is used when a small water channel is required but when the width of the water channel becomes greater, a multiple pipe culvert becomes necessary. Some of its advantages includes: ability to withhold any tensile stresses and compressive stresses and the crossing of water is under the structure, easy to construct to any design strength by proper mix design, thickness and reinforcement.

3. Pipe Arch Culvert.

Pipe arch culvert are suitable for waterway openings where fishes can be provided with a greater hydraulic advantages but with a stable flow capacity. Pipe arch culvert are good for the sewage and fishes because they can use the drainage easily without stocking the flow at the bottom. This type of culvert have a very beautiful appearance and are useful in many places. Some of its advantages include: aesthetic shape and appearance, lightweight and easy to install, limited headroom condition and improved hydraulic capacity at low flow.

4. Arch Culvert.

These type of culvert are similar to pipe arch culvert but the differences between the two is that in arch culvert, there is a mat provided at the bottom of the arch. The passage of the arch is very wide and can transmit a very large flow of water. The type culvert can be made of material or steel. Arch culvert can be made from the following material like metal, concrete, metal, masonry. It can be termed as a low profile culvert because it takes less time to construct unlike the box culvert and water diversion is not really necessary since it can be installed without disturbing the water current. This type of current maintains the natural integrity of the wash bed. Some of its advantages includes: cost saving, pleasing aesthetics, design-build advantages, accelerated construction scheduled and greater hydraulic efficiency.

5. RCC Solid Slab Culvert.

Solid slab culvert is provided where big canals and rivers are also used as a bridge for road vehicles. During the construction of this type of culvert, foundations are laid under the ground surface followed by laying a series of box culvert in the ground, then pavement is placed on the top surfaces.

Fig. 1 A Box Culvert (Foley product, 2023)   Fig. 2 Pipe Culvert (Civil Engineering, 2023)

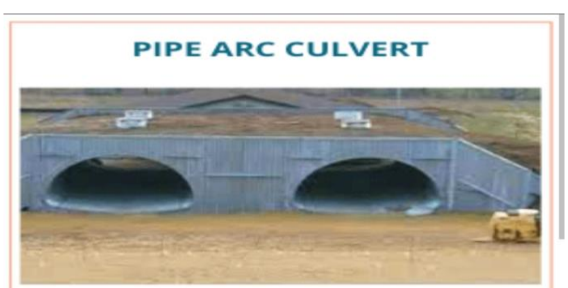


Fig. 3 Pipe Arch Culvert (Civil Engineering, 2023)   Fig. 4 Arch Culvert (ArchExpo, 2022)

Fig. 5 RCC Solid Slab culvert (Daily Civil, 2023).

2.10 Structural Elements of Box Culvert.

The structural element of a box culvert typically includes the following:

1. **Footings:** These are structural elements that supports the box culvert and transfer the load from the structure to the ground. Footings are usually designed based on the soil properties, the load acting on the structure, and the geometry of the structure.
2. **Walls:** Box culvert wall are vertical components that encloses the structure. These walls are typically made of reinforced concrete and are designed to withstand the loads acting on the structure, including the weight of the fluid or water flowing through the culvert.
3. **Slab:** The slab is a horizontal component of a box culvert that forms the top of the structure. It is usually reinforced with the steel to provide additional strength and durability.
4. **Headwalls:** Headwalls are the end sections of the box culvert that help to redirect and control the flow of water or other fluid entering or leaving the culvert. They are usually made of reinforced concrete and can be design to incorporate weirs, baffles, or other features to improve the hydraulic performance of the culvert.
5. **Wing walls:** Wing wall are the sloping components of the box culvert that extend from the headwall to the embankments or abutments of the structure. They are designed to provide the additional support and stability of the structure, as well as to redirect the flow of water or the other fluids away from the embankments or abutments.

Overall, the structural elements of the box culvert are designed to provide a safe and durable passage for the flow of water or other fluids under the structures. The design of these element takes into account the loads acting on the structure, the properties of the surrounding soil, and the hydraulic characteristics of the fluid flowing through the culvert.

2.11 Structural Analysis and Design

Structural analysis involves the identification of the loads acting on the culvert as well as their magnitude and direction in order to ascertain their effects on the structure. These effects refer to the bending moments, shear and axial stresses, deflection and so on.

Design is the process of selecting the appropriate dimension of the structural elements with respect to the strength characteristics of the construction material (concrete in this case) that will adequately resist the stresses generated by the loads:

2.11.1 Loading

A box culvert is subjected to various loads. These loads could be vertical or lateral loads which can be classified as dead loads or live loads and can be estimated in the different ways under different circumstances.

According to Reynolds and Steedman (1999), "The loads on a box culvert can be conveniently divided as follows:

1. A uniformly distributed load on the top slab and an equal reaction from the ground below the bottom slab.

2. Concentrated imposed load on the top slab and an equal reaction from the ground below the bottom slab.

3. An upward pressure on the bottom slab due to the weight of the walls.

4. A uniformly distributed horizontal pressure on each wall due to the increase in earth pressure in the height of the culvert.

5. A uniformly distributed horizontal pressure on each wall due to pressure from the earth and any surcharge above the level of the roof of the culvert.

6. The internal horizontal and possibly vertical pressures from water in the culvert.

Where a trench has been excavated in firm ground for the construction of a culvert and the depth from the surface of the ground to the roof of the culvert exceeds, say, three times the width of the culvert, it may be assumed that the maximum earth pressure on the culvert is that due to a depth of the earth equal to three times the width of the culvert. Although a culvert passing under a newly filled embankment may be subjected to more than the full weight of the earth above, there is little reliable information concerning the actual load carried and therefore any reduction in the load due to arching of the ground should be made with discretion. If there is no filling and wheels or other concentrated loads can bear directly on the culvert, the load should be considered as carried on a certain length of the culvert. The concentration is modified if there is any filling above the culvert and, if the depth of the filling is h1, a concentrated load F can be considered as spread over an area of 4h1. When h1 equals or slightly exceeds half the width of the culvert, the concentrated load is equivalent to a uniformly distributed load of F/4H12 in units of force per unit area over a length of culvert equal to 2h1.

The weight of the walls and top (and any load that is on them) produce an upward reaction from the ground. The weights of the bottom slab and the water in the culvert are carried directly on the ground below the slab and thus do not produce bending moments, although these weights must be taken into account when calculating the maximum pressure on the ground. The horizontal pressure due to the water in the culvert produces an internal triangular or a trapezoidal load if the surface of the water outside the culvert is above the top slab. The magnitude and distribution of the horizontal pressure due to the earth against the sides of the culvert can be calculated in accordance with the formulae given in the table 16-20, consideration being given to the possibility of the ground becoming water logged with consequent increased pressures and possibility of floatation."

Oyenuga (2001) stated that "A box culvert consists of three elements that is, top slab, walls and bottom slab and the loads on each component are as follows:

Top slab: The load will include slab own weight, imposed load and weight of earth fill. In cases where the depth of the earth fill is greater than three times the width of the culvert, the earth load can be assumed to be equal to earth loads of height three times the culvert width. Should be based on tyre width. For a wheel load of height, h, the load should be spread over an area of 4h2, which is 2h by 2h. When h equals or slightly exceeds one half of the width of the culvert, the wheel load can be assumed as equivalent to a uniformly distributed load of W/4h2 where W is the wheel load. Wheel loads are given in units of 2.5KN and the most common HB loads are 30 and 45units equivalent to 75KN and 112.5KN respectively. Critical culverts should be designed for 45 units HB loads and the number of wheels that incident on the culverts noted. For this project, critical HB loading of 45 units was adopted, a 3m depth/height of fill above the top slab was chosen.

Walls: Loads on walls include own weight, effect of active earth pressure, the effect of any the inside wall and the wall should be designed to resist this pressure and assuming no back fill is done. The walls need not to be design as tank walls, that is, there is no need to check for stresses in the steel as well as checking for crack widths. The wall should simply be design for flexure (bending, shear and axial pull).

Bottom slab: The top slab and its imposed load, the walls and the pressures on them produce an upward pressure (reaction) from the ground and causes moments. The weight of the water in the culvert and the weight of the bottom slab should be considered when determining the maximum pressure on the ground but since they borne by the ground directly, they do not generate moment.

According to ASSHTO specification section 12, "When the depth of fill exceeds 2.4m, live load is ignored."

Punmia, Jain and Jain (1992) stated that, a box culvert is subjected to soil load from outside and water load from inside. The vertical walls are subjected to earth pressures from outside and water pressure from inside. Similarly, the bottom slab will be subjected to soil pressure from outside and water pressure from inside. The top slab will, however, be subjected to embankment weight and traffic loads, if any." The weight of bottom slab of a box culvert will be resisted by equal and opposite soil pressure without bending in the bottom slab.

2.11.2 Load Cases

According to Oyenuga (2001), "Two conditions should be considered as follows;

a. Culvert Empty: Full load on top of the slab, surcharge load and earth pressure on the walls.

b. Culvert full: Minimum load on top of the slab (e.g. own weight), minimum earth pressure (if possible, none), on walls and maximum lateral water pressure on the walls should the area be water logged, the pressure on the wall will be trapezoidal and they will be upward water pressure (equal to the weight of water above the surface of the top slab) on the top slab and should be taken into consideration". After analyzing both load cases he stated that, "these loads are less than case 1 loads excepts for the wall loads and practically speaking if the culvert is flooded with water would be on both side of the walls cancelling the net water pressure on the walls. The case 1 loads can therefore be used for design purposes". In the above equation, "these loads" refer to culvert full while "case 1" refers to culvert empty.

Sinha and Sharma (2009) stated that, "mainly three load cases govern the design. These are given below;

a. Box empty, live load surcharge on top slab of box and superimposed surcharge load on earth fill. b. Box inside full with water, live load surcharge on top slab and superimposed surcharge load in earth fill. c. Box inside full with water, live load surcharge on top slab and no superimposed surcharge on earth fill." In this project two load cases will be considered. That is, culvert empty and culvert full as stated by Oyenuga(2001).

2.11.3 Analysis and Design

Box culverts shall be analyzed as closed rigid frames. The dead and superimposed earth loads, the lateral earth pressure, and the live and impact load are to be analyzed separately. The result of these separate loading conditions shall be assembled in various combination to give maximum moment and shear at the critical points. That is, the corners and the positive moment areas. Appropriate load positions shall be used to produce maximum positive and minimum moments. A maximum of one half of the moment caused by lateral earth pressure, including any live load surcharge may be used to reduce the positive moment on top and bottom slabs."

There are several methods of analyzing rigid frames. They include;

1. Displacement method.

2. Method of force.

3. Moment distribution method.

Oyenuga stated that, "a box culvert should be analyzed as a rigid structure with moment occurring at the corners. The hardy cross method of moment distribution is best suited for culvert analysis or the kani's method of moment distribution."

According to AASHTO specification section 12, (1998), Buried structures and tunnel liners, shall be analyzed and designed as rigid frames."

Reynolds and Steedman (1988) stated that, "the bending moments produced in monolithic rectangular culverts may be determined by considering the floor slabs as a continuous beam of four spans with equal bending moments at the end support. But, if the bending of the bottom slab tends to produce a downward deflection, the compressibility of the ground and the consequent effect on the bending must be considered.

Oyenuga (2001), further stated that, "due to the interconnections of the members, the shear in the walls introduces axial forces in the slabs and vice. Hence each element must be designed for moment and axial pull (just as a column that is subjected to bending and axial pull."

In this project, the structural members will be designed as columns subject to bending and axial pull.

2.11.4 Reinforcement

Oyenuga (2001) stresses that the designer should, "should note the u-bars provided at the corner to carter for torsional effects". He also stated that a minimum steel reinforcement of 0.4%bh be provided in the structural members. Where b= 1000mm length of the culvert and h= depth of the member.

2.11.5 Dimensions and specifications

According to AASHTO specification section 12, "the minimum top and bottom slab thickness is 200mm. All cells of multiple cell reinforced concrete box (RCB) culvert shall be the same size. The minimum height of RCB culvert is 1.25 vertical clearance to allow for inspection. Four sided boxes can typically be used for spans up to 3.5m span length from 3.4m to 7.5m are typically bridges using three sided rigid frames."

The thickness of walls and slabs of a box culvert shall be not less than 250mm for members with reinforcement in both faces.

If the top slab is to be used as the road way wearing surface, then it shall have a 50mm-75mm concrete top reinforcement cover. Additionally, the top slab concrete shall be 4500 psi minimum strength, and the top math of reinforcing steel shall be epoxy coated. When the top slab is not the riding surface, the earth cover provided hall be not less than 22.86cm (in addition to paving) at the minimum point.

Construction joints shall be provided at approximately 9m. Expansion joints shall be provided at approximately 27m intervals. Reinforcement shall be stopped two inches clear of joints. Head walls shall be provided at the exposed ends of culverts to retain the earth embankment and to act as edge distribution beams.

In other to provide for the effect of scour, cut- off walls in a minimum of 0.9m deep shall be provided at the exposed end of the culverts.

Wing wall footing shall be set at the elevations of the cut-off walls and securely toed to them with reinforcement."

In this project, the slabs and walls are 350mm thick and the top slab has a concrete cover 50mm although it carries an embankment of 2m.

Chapter Summary

Chapter two of this research project centers on explaining what drainage is and describing in detail the essence of drainage and its relationship with road construction. General consideration in road design and drainage are also discussed. The consideration also extends to the design of surface drainage through hydrological analysis and hydraulic analysis to obtain the storm water runoff rate.

CHAPTER THREE

METHODOLOGY

3.0 Location Analysis

For the Enugu-Onitsha express road, drainage system study and design were done. This route may be found in the southern section of Awka, in the state of Anambra. It is approximately 0.75 kilometers long. (Google Map Data, 2018). It has a rectangular, open double side drain system that is roughly 0.8 m wide and 0.6 m deep. The road is situated in the moderately populated (mainly civil servants) section of the capital city of Anambra state, Nigeria, and is primarily flanked by residential and commercial structures.

3.1 Data Collection

For the study, two different types of data were gathered: primary data from a field survey and secondary data from a desk study.

3.1.1 Desk Research

Data regarding the geometric design, building, and maintenance records of the researched roadways were gathered through the review of documents. This information was gathered from the state of Anambra's ministry of works. In order to show the current state and any associated obstacles in the drainage infrastructure and the road pavement, pictures were taken straight from the road sites during the field study.

3.1.2 Field Survey

In this study, a thorough field survey of the state of the pavements and drainage structures was completed. An automobile travelling slowly on the shoulders along the troubled areas performed a visual check of the pavement surface. Stops were made frequently close to places where extreme distress was seen. To find the drainage issues, drainage infrastructure that are intergraded with the route under study are surveyed. At these places, pictures of the failed drainage systems and pavements were also taken.

3.2 Storm Water Drainage System Design

This teaches how to size a drain to remove the extra water and how to estimate how much a catchment area will create. This technique can be used to design a drainage system, assess the sufficiency of an existing drainage system, or assess the viability of a proposed drainage system.

3.3 Estimation of Rainfall Intensity

The duration of the rain or time of concentration (Tc) was used to calculate the area's rainfall intensity (mm/hr.). The concentration period is the amount of time required for the water to go from the catchment's furthest point to the point at which it will depart the discharge point. The equations are used to calculate the duration of concentration.

$Tc = 0.02 \times L_{max}{}^{0.77} * (Sav)^{-0.383}$ ……...(3.1)

Where

T_{con}: The period during which one is focused (in minutes)
L_{max}: The catchment's maximum flow duration (in meters)
S_{av}: The catchment area average gradient

3.4 Estimating the Water Production from the Catchment Area

The peak storm water runoff rate was calculated using a rational technique equation, which is given below.

$Q=0.278CIA$

Where

Q is the drainage area's maximum storm water runoff rate (in m^3/s).

C is the runoff coefficient, determined by the terrain, vegetation, and soil characteristics.

A is the Catchment area.

I is the rainfall intensity in (mm/hr.).

After estimating the quantity of expected runoff, a design was created that can safely handle the estimated runoff.
The ratio of the runoff rate to the rainfall rate is expressed by the runoff coefficient, C. The watershed's time of concentration is represented by the variable tc. (Hours).

3.6 Prediction of Runoff

Rainstorms produce runoff, which depends on the features of the rainfall event, such as intensity, length, and dispersion, for both its occurrence and quantity.

Any drainage installation is scaled in accordance with the likelihood that an anticipated peak discharge will occur during the course of the facility's design life. Of course, this depends on how intense and long rainstorms are, not only those that happen near the building, but also downstream from the structure. Peak discharge in snow zones might be brought on by a period of strong heat that causes the snowpack to melt quickly.

The frequency, or how frequently the design maximum may be expected to occur, is another factor to be taken into account in addition to the intensity and duration of a peak rainfall event. This factor is typically dependent on the lifespan of the road, traffic, and the potential repercussions of failure. Frequency periods of 50 to 100 years are frequently used for primary highways, 25 years for subsidiary roads, and 10 to 25 years for low volume forest roads.

A portion of the water that falls as rain will percolate into the soil to be retained until it is absorbed by plants or transmitted via pores as subsurface flow, while the remainder will evaporate back into the atmosphere and contribute to overland flow or runoff. Stream flow is made up of both water that is contributed to the channel more quickly as the drainage net widens to accommodate extra rainfall during a major storm event and stored soil moisture that is supplied to the stream at a more or less constant rate throughout the year in the form of subsurface or groundwater flow. The following variables affect the amount of rainfall that eventually turns into stream flow:

1. The drainage area's size. The amount of runoff increases with area size. Use of runoff formulas and charts requires an estimation of basin area.

2. The topography. In general, slope steepness corresponds to an increase in runoff volume. Even though they aren't frequently specified in the majority of runoff calculations and charts, average slope, basin elevation, and aspect may offer useful hints for optimizing a design.

3. Soil. The permeability and infiltration capacity of the soil are particularly important in determining runoff. Given a constant rainfall rate, the infiltration rate of a dry soil will gradually decrease over time as it becomes wetted due to its inherent permeability. If a rainfall rate exceeds the soil's final infiltration rate (infiltration capacity), Water that cannot be absorbed is either held in ground depressions or flows off the surface. The amount of runoff will rise under any circumstance that has a negative impact on the soil's infiltration properties. The hydrophobicity, compaction, and frozen ground are a few examples of such circumstances.

There are numerous approaches available to forecast peak flows. When enough hydrologic data is available, the most accurate method is flood frequency analysis. For instance, based on regional data gathered from "gaged" streams, the United States Geological Survey has released empirical equations offering estimates of peak flows from streams in several sections of the United States. According to frequency analysis, the drainage area and precipitation intensity for the 2-year, 24-hour storm event are most closely connected with discharge in northwest Oregon for the flow event with a 25-year repetition interval. Since the recurrence interval connected to any particular flow event can be recognized and utilized for assessing the chance of failure, this is by far the best method for calculating peak flows on an ungagged stream

.

A planned stream crossing installation's design approach should take into account the likelihood that peak flows would surpass its design capacity. The risk of failure over the design life must be indicated in order to include this knowledge in the design. The land manager formally states the desired level of success (or failure) to be attained with road drainage systems by determining an acceptable level of risk. Flood recurrence intervals for installations are shown in Table 3.2 in relation to their design life and failure probability.

Table 3.0 Flood Recurrence Interval (years) in Relation to Design Life and Probability of Failure. (Megan, 1977).

Design Life (Years)	**Chance of Failure (%)**						
	10	**20**	**30**	**40**	**50**	**60**	**70**
	Recurrence interval (years)						
5	48	23	15	10	8	6	5
10	95	45	29	20	15	11	9
15	100+	68	43	30	22	17	13
20	100+	90	57	40	29	22	17
25	200+	100+	71	49	37	28	21
30	200+	100+	85	59	44	33	25
40	300+	100+	100+	79	58	44	34
50	400+	200+	100+	98	73	55	42

According to the formula $P = 1 - (1-1/T)^n$,

Where n = design life (years),

T = peak flow recurrence interval (years),

P = likelihood of failure (%).

3.6.1 Calculating the Runoff Coefficients

For the reasons outlined in section 3.7, it is best to avoid using runoff coefficients that have been calculated for watersheds in other regions when designing a water harvesting system. Small catchment areas should not be subjected to runoff coefficients for large watersheds.

It would be desirable to base an analysis of the rainfall-runoff relationship and a subsequent evaluation of pertinent runoff coefficients on actual, concurrent observations of both rainfall and runoff in the project area.
As previously stated, the runoff coefficient from a specific rainstorm is calculated by dividing the runoff by the matching rainfall, both represented in terms of depth over catchment area (mm):

In order to establish a representative range, actual measurements need be made. Before beginning a more extensive construction program, Shanan and Tadmor advise waiting at least two years to measure rainfall and runoff data. In any case, such a period of time would be appropriate in light of the detrimental demonstrative effect a water harvesting project would have in the event that the structures were severely damaged or destroyed during the first rainstorm because the design was based on inaccurate runoff coefficients.

Usually, a fair connection is seen when plotting the runoff coefficients against the pertinent rainfall depths.
If measurements of the matching rainstorm strength, duration, and antecedent soil moisture were made in addition to rainfall depth, a considerably greater correlation would be found.

This would enable the plotting of the runoff coefficients against the pertinent rainfall durations individually for various intensities, as well as the grouping of rainstorm occurrences based on their average intensity and antecedent soil moisture.

Using an autographic rain gauge that records rainfall constantly, rainfall intensities can be precisely measured. By dividing the measured rainfall depths by the corresponding storm durations, it is also possible to time the length of individual rainstorms and determine the average intensities.

3.6.2 Evaluation of Seasonal or Annual Runoff

Here, a technique is utilized to determine how much storm water a catchment area will create and how big a drain needs to be to remove it. This technique can be used to design a drainage system, assess the sufficiency of an existing drainage system, or assess the viability of a proposed drainage system. (Rottier and Ince, 2003).

The ability to predict runoff peaks that a water harvesting scheme's structure must be able to withstand as well as the required capacity for runoff's temporary surface storage, such as the size of an infiltration pit in a micro catchment system, depends on knowledge of the runoff from individual storms as previously described.

In contrast to runoff coefficients obtained from individual storms, the annual (seasonal) runoff coefficient additionally accounts for rainfall episodes that did not result in any runoff. The arithmetic mean of the runoff coefficients generated from individual runoff-producing storms is consequently never smaller than the annual (seasonal) runoff coefficient.

3.7 Sizing a Drain to Handle the Peak Runoff Rate Designed

A drainage system must be developed in conjunction with other structures, such as roads and buildings, to ensure that they are all adapted to one another. Once the design peak runoff rate is known, the characteristics of the drainage need to be determined. Unlined drains should have a relatively low gradient to reduce the risk of erosion while still regulating storm water velocities. Gradients in unlined drains shouldn't likely be higher than 0.005. (1 meter drops in 200 meters horizontal distance). Unlined drains should be constructed with a slope that is less steep than 1/2 in less stable soil, and a steeper slope may be used in more cohesive soil. (Rottier and Ince, 2003).

Sizes of the drain can be calculated with the formula:
$$\mathbf{Q=1/N\ (A \times R^{0.67} \times S^{0.5})}$$

Where:

Q: the capacity of discharge of the drain (in m^3/s)

R: the hydraulic radius of the drain in m^2

A: The cross section of the drain

S: the gradient of the drain

N: Manning's roughness coefficient for concrete lined channel, 0.02

Hydraulic radius = (a x b) / (a + b + c)

3.8 Drainage System Structural Design

Design Guidelines

It makes advantage of the limit state design idea. The working loads are multiplied by partial safety factors in the limit state technique, and the ultimate strength of the material is divided by partial safety factors as well. The serviceability limit state (SLS) and the ultimate limit state (ULS) were the two main limit states taken into consideration. The structure was examined for the serviceability limit state (against deflection and cracking) and built for the ultimate limit state (against collapse). (Mosely and Boungey, 1987). Beginning with an assessment of all the loads carried by the drainage structures, including their own weight, structural analysis was performed.

3.8.1 Design Loads

The ultimate load used in design is obtained by multiplying the characteristic load by a partial safety factor. For dead and live loads, the ultimate load, n is given as
n = 1.4gk +1.6qk

where,

g_k = dead load

q_k = live load

For the reinforced concrete drainage channels, the following design data were used.

Unit weight of reinforced Concrete = 24 kN/m^3

Unit weight of water = 9.81 kN/m^3 (Reynolds, 1997).

Characteristic strength of concrete, fcu = 25 N/mm^2

Characteristic strength steel, fy = 410 N/mm^2

Loading on the side walls of the drain
Using Rankine's formula, lateral earth pressure at the base of the wall of height, h is given by

Pa = Ka x r x h

Earth thrust, **Pa = 1⁄2Kaxrxh^3** acting at **h/3** from the base

The moment at the base of the wall is

Ma = Pa ×h/3= 1/6 ×Ka× r ×h^3

Ka = coefficient of active earth pressure **(1 - sin¶) / (1 + sin¶)**

¶ = the angle of internal friction of the soil

r = unit weight of the soil, kN/m^3

h = height to the base of the wall, m.

3.8.2 Reinforced Concrete Design Procedure

The ultimate moment**, Mu = 1.4 × the Service Moment**

Once Mu was obtained, for a section with effective depth, d and breadth, b

K=Mu / (bd^2 x fcu) was estimated

For singly reinforced sections, **k < 0.156**

The lever arm was estimated using **Z= d (0.5+ (√ (0.25-k/0.9))**

BS 8110 specifies an upper limit of **Z=0.95d**

The area of steel reinforcement required is calculated from **AS = M / (0.87fyz)**

(Bosely and Bungey, 1987).

The load acting on the base slab was taken as an equivalent uniformly distributed load calculated as the weight of the drain and weight of water in the drain divided by the effective width of the base slab

Q = (W1+ W2) / L

Where,

Q = Equivalent uniformly distributed load, kN/m^2

W1= Self weight of the drain, kN

W2= Weight of water in the drain, kN

L= Effective width of the base slab, m

The maximum moment which occur on the Centre of the base slab, was calculated as $\mathbf{qL^2/8}$

There are three widely used techniques for navigating channels on low traffic roads: bridges, fords, and culverts. The decision is made based on the volume and nature of the traffic, the site's hydrologic and hydraulic conditions, and management requirements such as temporary closures, ongoing use, safety considerations, and resource impact (fish, wildlife, sediment).

3.9 The Following is a List of the Considerations to Make When Choosing a Crossing Type:

1. Bridges: high traffic flow, big and fluctuating water volume, high potential for debris, sensitive channel bottom and banks, important fish resource, significant elevation difference between channel and road grade

2. Culvert: Medium to low water volume, medium to low debris potential, fish resource not significant, elevation difference between channel and road grade less than 10 meters, high traffic volume

3. Ford: low to inconsistent water flow, high possibility for trash, no fish resource, road grade can be lowered to channel bottom, low traffic volume

Each of the three types of channel crossings necessitates a thorough evaluation of both vertical and horizontal alignment. In particular, a thorough consideration of the needs for curve widening in respect to the designated critical vehicle is essential. Fixed infrastructure, such as channel crossings, prevent the road's width from being temporarily increased. The size of the vehicle that can cross the crossing depends on the road's width, curvature, approach, and exit tangents.

Wherever possible, roads should ascend away from channel crossings in both directions, with the exception of bridge locations, to prevent high water from flowing down the road's surface. For installations involving Ford, this is especially true.

3.10 Box Culvert Structural Analysis and Design

The dynamic pedestrian load is the imposed load taken into account. Additionally taken into account are the pressures of water, hydrostatic systems, and the ground. The self-weight of the culvert structure's individual parts is included in the dead loads. For culverts with load lengths between $L < 36m$, the uniformly distributed pedestrian load intensity should be around $5KN/m^2$ (Reynolds and Stedman, 1999). A pedestrian load of $4KN/m^2$ will be used for the research's design.

The drainage system's Q for discharge also applies to the culvert. The drainage dimensions were used to determine the culvert size.

Maximum shear and bending moments that could be encountered by the Culvert due to wheel load, water, and the earth pressure.

Corrugated metal pipe (CMP)	**All conditions**
CMP with paved invert	Water carries sediments erosive to metal
CM pipe-arch	Low fills; limited head room
Multi-plate	Large sizes (greater than 1.8 meters)
Reinforced concrete pipe (RCP)	Corrosive soil or water, as salt water; short haul from plant; unloading and placing equipment available
Reinforced concrete box	Extra-large waterway; migratory fish way

3.10.1 Box Culvert Loading

Dead and forced loads were taken into account for the bridges. 45 units of HB loading were the applied load taken into account. Additionally taken into account were the pressures of water, hydrostatic, and the ground. The self-weight of the structure and the surcharge loads resulting from the fill materials are included in the dead loads. These divisions of the loads on the culvert made sense of the following;

1. A uniformly distributed load on the top slab and reaction from the ground below the bottom slab.

2. A concentrated imposed load on the top slab and reaction from the ground below the bottom slab.

3. An upward pressure on the bottom slab due to the weight of the walls.

4. A triangularly distributed horizontal pressure on each wall due to the increase in earth pressure in the height of the culvert.

5. A uniformly distributed horizontal pressure on each wall due to pressure from the earth and any surcharge above the level of the roof of the culvert.

3.11 Bills of Engineering Measurement and Evaluation (BEME)

To provide a realistic calculation of the project cost, bills of engineering measurement and evaluation (BEME) depicting the amounts of items of work to be created, completed, and maintained have been prepared from the draft final engineering design drawings. The Civil Engineering Standard Method of Measurement (CESMM 3), 3rd Edition, 1991, republished with amendments in 1992, and published by the Institution of Civil Engineers, UK in collaboration with of Civil Engineering Contractors, served as the basis for the preparation of the BEME. It was changed to fit Nigerian custom.

3.11.1 Estimated Cost Basis

The unit prices used to create the draft final cost estimate were based on the items of work measured from the draft final engineering drawings. They include the fundamental costs of construction materials, labor, and related plant and equipment, as well as the costs of comparable projects in Nigeria in April 2016. The unit prices also contain a provision for contingencies and value added tax, as well as the expenses of material handling and freight, labor, and associated plant, overhead, and profit. (VAT). Every unit cost is set at the prices in effect in Nigeria in April 2016.

The anticipated overall cost of performing the project has physical contingencies built in to account for work quantity overruns.

3.11.2 Introduction/Preliminary

The Engineer or Quantity Surveyor typically introduces themselves to the contract in the preliminaries part of the bill of quantities. Site clearing, the creation of a backup linkage, water redirection, and site preparation for the drains and culvert were allotted funds for the preliminary work.

3.11.3 Schedule for Structural Detailing and Bar Bending

The AutoCAD software was used to create the design output draft. The autocad software was used to create the layouts, details, models, and schedule for bar bending.

CHAPTER FOUR

DESIGN, COSTING AND DISCUSSION

4.0 Design of Drainage System

REFERENCE	CALCULATION	RESULT
This data was collected from ministry of works in Anambra State, it is delineate on Topographical map	**4.1 Design of Side Drains** Catchment area (Area contributing flood to the drain Length of the Catchment area) = 3.5 km = (3500) Width of Catchment area = 7.3m each = 14.6m = 0.015km Area of Catchment = $0.0525km^2$ **Design flow/Discharge** The design flow was determined using the rational formula **Q = 0.278 CIA** Where Q = Discharge/flow (m^3/s) C = run-off coefficient depending upon topography vegetation and soil condition I = intensity of rainfall (mm/hr) A = Catchment area (km^2)	
Kirpich Method -1940	The time of concentration (Tc) or duration of rainfall in getting the rainfall intensity (mm/hr) $\mathbf{Tc = 0.0195 \times (\frac{L}{S^{1/2}})^{0.77}}$ Where Tc = Time of concentration (mins) L = Length of Catchment area (m) S = average slope of the Catchment area Assumed slope as 0.001 $Tc = 0.0195 \times (3500/0.001)^{0.77} = 149.3$ mins Appendix C Taking a return period of 10 years see Appendix A	T_c = 149.3 mins

	Checking a return period of 10 years against rainfall intensity or duration (Tc) of 149.3 mins gives a rainfall intensity (I) of I = 120mm/hr C = 0.85 see Appendix B A = 0.0525km^2 A = 0.0525/2 = 0.03 Q = 0.278 x 0.85 x 120 x 0.3 = 0.85m^3/s Having determined the amount of expected run-off, facility that will safely accommodate the estimated run-off was designed. Since it is an open channel condition (with free surface exposed to the atmosphere), the manning formula will be used to design the required facility. **Q = AV** **But V = 1n ($R^{2/3}$ x $S^{1/2}$)** **A = 2Y^2** **Q = 1/n ($R^{2/3}$ x $S^{1/2}$) x 2Y^2** Where Q = discharge in m^{3}s n = manning's coefficient A = cross sectional area of channel in m^2 R = hydraulic radius = A/P in m P = wetted perimeter in m S = slope of channel in m/m Substituting values into the manning's formula to get the best hydraulic section. See Appendix D For fresh concrete n = 0.013 $0.85 = 1/0.013[(Y/2)^{2/3} \times S^{1/2}] \times 2Y^2$ $0.85 = 1/0.013[(Y/2)^{2/3} \times (0.001)^{1/2}] \times 2Y^2$ $0.85 = 76.923[(Y/2)^{2/3} \times 0.03162] \times 2Y^2$	Q = 0.85m^3/s

$0.85/76.923 = [(Y/2)^{2/3} \times 0.03162] \times 2Y^2$

$0.01 = [(Y/2)^{2/3} \times 0.03162] \times 2Y^2$

$0.01/2 = [(Y/2)^{2/3} \times 0.03162] \times Y^2$

$0.01 = Y^2 \times 0.01992y^{2/3}$

$0.01/0.01992 = Y^{8/3}$

$(0.502)^{3/8} = (Y^{8/3})^{3/8}$

Y = 0.8m

y = b/2

b = 2y

b = 2 x 0.8 = 1.6m

Proportioning Drain Size

For slope, S = 0.001

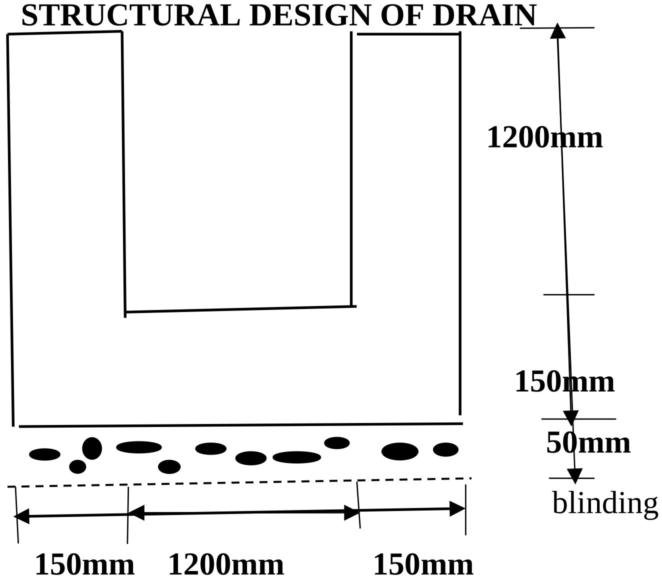
Compute the section factor $AR^{2/3} = Q(n/S^{1/2}) = 0.33333$

b m	Y m	A=b x y m^2	P= b-2y m	R = A/P m	$R^{2/3}$	$AR^{2/3}$	$Q(n/S^{1/2})$ 0.01/0.03	Fb
0.8	0.8	0.64	2.4	0.27	0.27	0.26	0.33333	0.2
1.2	0.6	0.72	2.4	0.3	0.446	0.321	0.33333	0.2
1.2	1	1.2	3.2	0.38	0.52	0.624	0.33333	0.2
1.6	0.8	1.28	3.2	0.4	0.541	0.693	0.33333	0.2
1.5	1.3	1.95	4.1	0.48	0.61	1.19	0.33333	0.2

Although a section of 1.6 x 0..8 can drain the Enugu-Onitsha express road of with discharge Q $0.85m^3/s$, for the above slope a minimum section of b = 1.2m by y = 1m

Since

$AR^{2/3} > Q(n/S^{1/2})$

	Freeboard (fb)	Y = 0.8m
	Add freeboard Fb = 0.2	
	Total depth of drain = Y + Fb = 1+0.2 = 1.2m	
	Provide a drain size, 1.2m x 1.2m	b = 1.6m
	For Velocity	
	Q = AV	
	V = Q/A = 0.85/1.2 = 0.71	
	Check Froude number, Fu	
	Fu = V/(gy)½	
	Fu = 0.71/(9.81x 1)½ = 2.22	
	STRUCTURAL DESIGN OF DRAIN	
		
	DESIGN DATA:	
	Characteristic strength of concrete, fcu = 25N/mm²	
	Characteristic strength of steel, fy = 410N/mm²	
	Unit weight of concrete, ¥ concrete = 24KN/m³	
	Unit weight of soil, ¥ soil = 18KN/m³	Use 1.2m x 1.2m
	Angle of internal friction of soil, μ = 18°	
	Soil cohesion, c = 12.4KN/m²	

	Unit weight of water, ¥w = 9.81KN/m³ **Design** Based on per meter length of basin Analysis is done for two (2) conditions: 1. When the drain is empty, and 2. When the drain is full of water Effective height of earth retained, H = 1.2m Preliminary Sizing: Effective height of wall = 1200mm Assume bar Size = 16mm Wall thickness d_{min} = H/10 = 1200/10 = 120mm Add cover = 50mm Add 1/2 bar size = 16/2 = 8mm Wall thickness, h = 120+50+8 = 178mm	V = 0.71m/s Fu = 2.22

H (m)	d_{min} (m)	d_{min} (mm)	Cover (mm)	1/2 bar	h (mm)
1.2	0.12	120	50	8	178

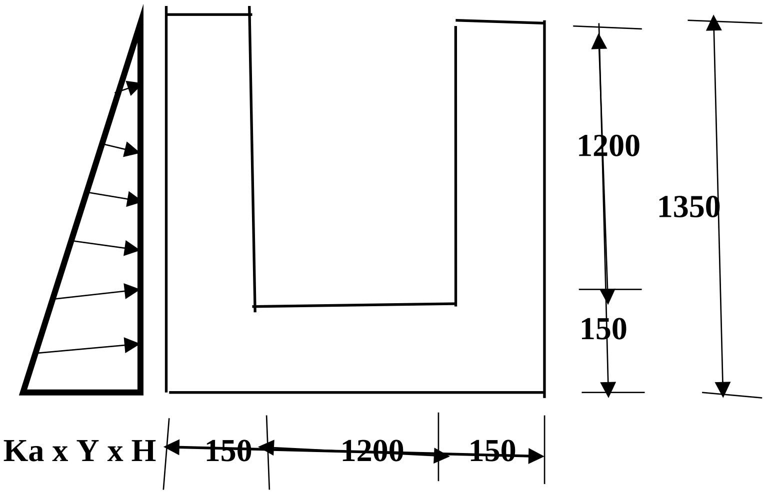
Try base thickness = 150mm = 0.15m

Try wall thickness = 150mm = 0.15m

Internal width, b = 1.2m

BS 8110 Clause 5.1.4.2 Table 5, 6,13

CASE: 1 DRAIN EMPTY (Earth pressure acting)



Lateral earth pressure, Pa

Ka = tan²(45 - Ø /2) = tan²(45-18/2) = 0.53

pa = Ka x y x H = 12.9KN/m² ≈13KN/m²

Horizontal thrust Pa

Pa = 1/2 x Ka x y x H² = 8.69 KN/m ≈ 8.7 KN/m

Moment due to horizontal thrust,Ma

Ma = Pa x H/3 = 8.69 x (1.35/3) = 3.91KN-m/m

Ultimate Moment MU = 1.4Ma

1.4 x 3.91 = 5.48 KN-m/m

Ø	45-Ø /2	Ka	y	H	H²	Pa	H/3	Ma
18	36	0.53	18	1.35	1.82	8.7	0.45	3.9

BASE

Effective span, Le

Le = b + (tw/2 + tw/2)

= 1.2+(0.15/2 + 0.15/2) = 1.35m

Weight of side wall, w

w = hw x tw x yconc.

1.35 x 0.15 x 24 = 4.86KN/m ≈ 4.9 KN/m

BS 8002

CL 2.2.4

Upward soil reaction at Base,

$q = 2w/Le = 2(4.86)/1.35 = 7.2KN/m^2$

L (m)	Le (m)	hw (m)	tw (m)	yconc.	Load, w	w (KN/m)	2w	q (KN/m²)
1.2	1.35	1.35	0.15	24	4.9	4.86	9.72	7.2

Free Peak Bending Moment at Base, $M = ql^2/8$

$(7.2 \times 1.82^2)/8 = 1.64KN\text{-}m/m$

Fixed Bending Moment, FEM at Base from lateral earth pressure

FEM = 5.48 KN-m/m

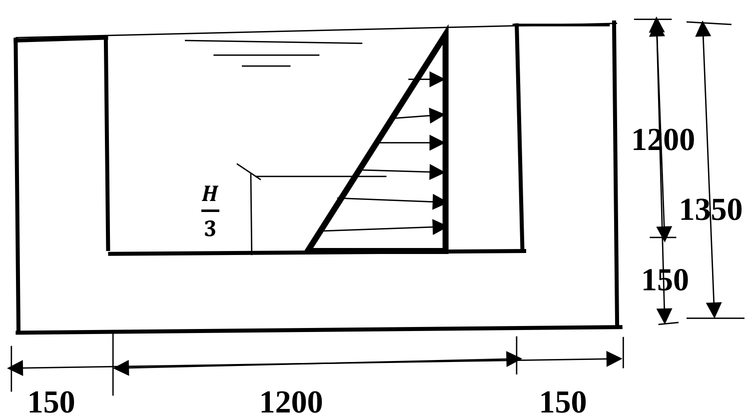
Net BM at Base = Mnet = Free BM -FEM = 1.64 - 5.48 = -3.84KNm/m

Ultimate Net Moment, MUnet = 1.4Mnet

1.4 x -3.84 = -5.38KNm/m

q	Le	Le²	M kNm/m	FEM	Mnet	MUnet
7.2	1.35	1.82	1.64	5.48	-3.84	-5.38

CASE 2 : DRAIN FULL (Water pressure acting)



pa = 12.9KNm

Pa = 8.69KNm

Ma = 3.91 KNm

MU = 5.48KNm/m

	Loading on wall : Depth of water, H = 1.2m Water pressure, pw pw = yw x h = 9.81 x 1.2 = 11.77KNm/m² Thrust due to water pressure, Pw 1/2 x yw x h² = 1/2 x 9.81 x 1.2² = 7.06KN/m Moment due to water Mw Mw = Pw x h/3 = 7.06 x (1.2/3) = 2.83KNm/m Ultimate Limit State Moment, MUw MUw = 1.4 x Mw = 1.4 x 2.83 = 3.96KNm/m	Mnet = -3.84KNm/m MUnet = -5.38KNm/m

yw	H	Pw	h²	Pw	h/3	Mw	MUw
9.81	1.2	11.77	1.44	7.06	0.4	2.83	2.83

BASE :

Weight of water, Pw

Pw =yw x h x b = 9.81 x 1.2 x 1.2 = 14.1KN/m

Weight of walls, Ww

Ww = tw x hw x yconc = (0.15 x 1.2 x 24) x 2 = 8.64KN/m

Upward soil reaction at Base, q

q = (Pw + Ww)/Le = (14.1 + 8.64)/1.35 = 20.53KN/m²

yw	h	B	Pw	Tw	hw	Yconc	Ww	q
9.81	1.2	1.2	14.1	0.15	1.2	24	8.64	20.53

Free Bending Moment at Base due to water, BM

M = ql²/8 = (20.53 x 1.82)/8 =4.68KN-m/m

Free Bending Moment at Base due to water pressure FEM

FEM = 2.83KN-m/m

Net BM at Base =

Mnet = Free BM - FEM = 4.68 - 2.83 = 1.85 KNm/m

Ultimate Net Moment, MUnet

MUnet= 1.4Mnet = 1.4 x 1.85 = 2.59KN-m/m

q	Le	Le^2	M	FEM	M	Mnet	Mnet	MUnet
20.53	1.35	1.82	4.7	2.83	4.68	2	1.85	2.59

SUMMARY OF MOMENT

CASE	**Bending Moment at wall**	**Bending Moment at Span of Base**
1	5.48	-5.38
2	3.96	2.59

The walls will be designed for Maximum Bending Moment, BM

BM = 5.48 KN-m/m

The base will be designed for Maximum Bending Moment, BM

BM = -5.38 KN-m/m

STEEL REINFORCEMENT

Wall

Mmax = 5.48 KN-m/m

h = 150mm

Mw = 2.83 KNm/m

MUw = 3.96 KNm/m

Pw = 14.1KN/m

Ww =8.64KN/m

M = 4.68KN/m

Mnet=1.85KN/m

Concrete Cover cc = 50

Assume Bar size Ø = 16mm

Assume 1m width = 1000mm

d = h - cc - Ø/2 = 150 - 50 - 16/2 = 92mm

MUnet = 2.59KN-m/m

h	Cc	Ø	D
150mm	50mm	16mm	92mm

K = M/(bd²fcu) = $5.48*10^6$/(1000 x 92² x 25) = 0.026

K = 0.026 < 0.15

La = (0.5 + √0.25 - K/0.9)

Use La = 0.95

K	$M*10^6$	b	d²	Fcu	K/0.9	√0.25 - K/9	La
0.026	5.48	1000	92	25	0.029	0.470	0.95

Z = La x d = 0.95 x 92 = 87.40mm

As req. = M/(0.87 x fy x Z)

= $5.48*10^6$/(0.87 x 410 x 87.4) = 175.78mm²/m

Use Y12 @ 300 (377mm²/m)

BM_w = 5.48KN-m/m

BM_b = -5.38KN-m/m

Distribution Reinforcement :

Min. Steel = 0.13%bh = (0.13/100) x 1000 x 150 = 195mm²/m

Use Y10 @ 200mm. (393mm²/m)

$M*10^6$	Fy	0.87fy	Z	As req.	0.13 %	b	h	Min. Steel
5.48	410	356.7	87.40	175.78	0.0013	1000	150	195

Bottom Steel

BS 8110 Clause 5.1.4.2 Table 5,6,13

Mmax = -5.38KN-m/m

h = 150mm

Concrete Cover, Cc= 50mm

Assume Bar size, Ø = 16mm

Assume 1m width = 1000mm

BS 8110 Part 1 - 1985 Clause 3.4.4

d = h- cc - Ø/2 = 150 - 50 - 16/2 = 92mm

K = M/(bd²fcu)

= $-5.38*10^6/(1000 \times 92^2 \times 25) = 0.025$

K = 0.025 < 0.15

h	Cc	Ø/2	d	$M*10^6$	b	d²	Fcu	K
150	50	8	92	5.38	1000	8464	25	0.025

La = (0.5 + √0.025 - K/0.9)

= 0.97 > 0.95,

Use La = 0.95

Z = La x d = 0.95 x 92 = 87.4mm

Mosley & Bungey -1987

As req. =M/(0.87 x fy x Z)

= $5.38*10^6/(0.87 \times 410 \times 87.4) = 172.57mm^2/m$

Distribution Reinforcement as per wall

TOP STEEL

As = 172.57 x (5.48/5.38) = 176mm²/m

Use Y12 @ 300. (377mm²/m)

Clause 5.1.4.2 Table 5,6,13

K/0.9	√0.25 - K/0.9	La	La	Z	Fy	M span (10^6)	M support (10^6)
0.471	0.028	0.97	0.95	87.4	410	5.38	5.48

As req. = $175.78mm^2/m$

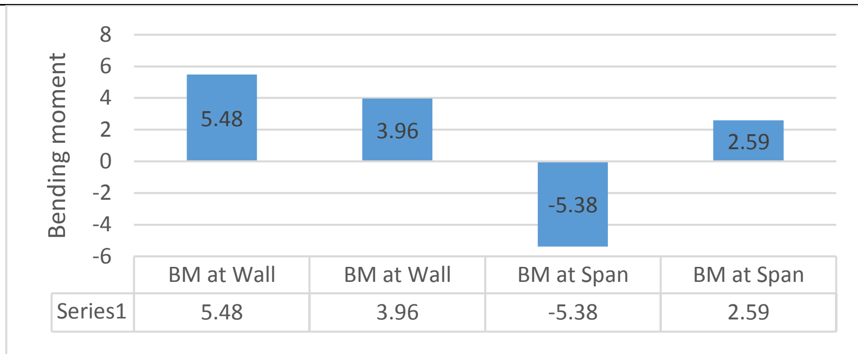
As prov. = $377mm^2/m$

As_{min} = $195mm^2/m$

Prov. $393mm^2/m$

BS 8110 Part 1 -1985

Clause 3.4.4.4



case 1. drain empty **case 2. drain full**

4.2. SUMMARY OF DESIGN OUTPUTS

The graph above displays a moment-by-moment summary for the above design. Following the determination of discharge Q, mannings coefficient n, and channel slope S on the aforementioned design. The drainage size was proportioned using the discharge. The process for determining the drainage size for drainage channel design involved first estimating the section factor, AR2/3 in terms of the drain width of flow, b, and its normal depth of flow, y, and then determining the normal depth of flow by trial and error. To get the needed total depth of drain, freeboard was then added to the typical depth of flow. The potential incidence of the loads was taken into account when calculating the bending moment. Generally speaking, these two factors were used to construct the drainage systems

1.Drainage Empty: Earth Pressure Acting

2 Drainage Full - Water Pressure Acting

Because of the condition's larger moment value caused by the action of lateral Earth pressure, case 1 analysis from the chart above was chosen for the design which displays the output from the previous design.

Use Y12 @ 300

($377mm^2/m$)

4.3. Design of Box Culvert

DESIGN INFORMATION

DESIGN OF 1.2m x 1.2m SINGLE CELL BOX CULVERT.

DESIGN DATA:

1. Concrete grade = $25N/mm^2$
2. Steel grade = $410N/mm^2$

3. Concrete density = 24KN/m³

4. Angle of internal friction Ø = 30°

5. Earth density ¥ = 18KN/m³

6. Coefficient of earth pressure at rest Ka = (1 - Sin Ø)/(1 + SinØ)

Ka = (1 - Sin 30)/(1 + Sin30) = 0.33

7. Assume Allowable Bearing Pressure = 100KN/m²

DESIGN CRITERIA

The corners of the one-cell box culvert were designed to operate as fully stiff joints. Therefore, the main reinforcement will go around the wall's corners. The coefficient of ground pressure at rest will be used because the culvert is thought of as a rigid structure.

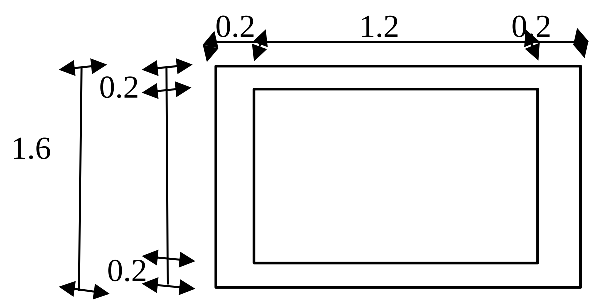
ACTUAL LOADS

The culvert was built to withstand 45 units of HB loads for the maximum number of wheels that could hit it. Here, it is assumed that the wheel load is comparable to a load of w/4h2, where (h) is the height of the earth fill and (w) is 112.5 kN/m2.

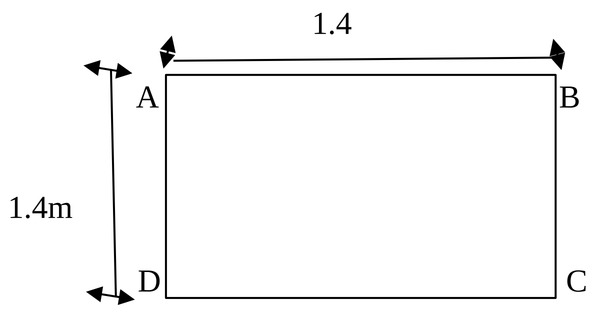
Example: 45 units of HB loading at 2.5 kN per wheel is 112.5 kN.

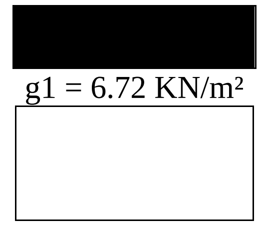
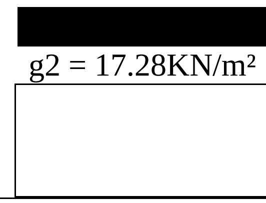
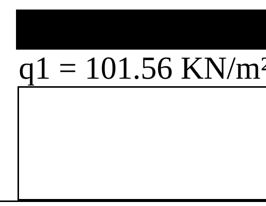
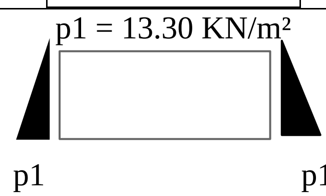
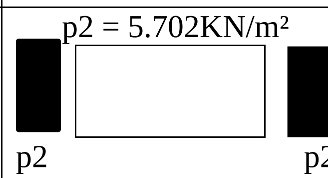
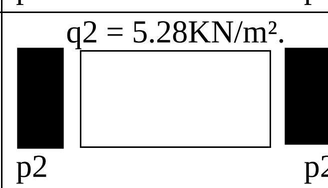
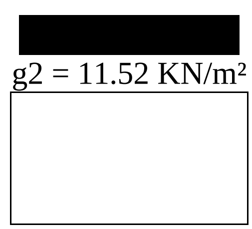
Cross Section

Assume slab thickness as 200mm



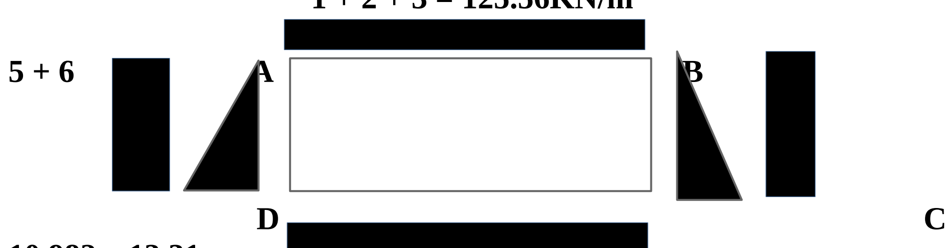
DESIGN DIMENSIONS



LOAD ON THE BOX CULVERT - THE PRESSURE TABLE			
LOAD	NOMINAL LOAD	DESIGN LOAD	LOAD DIAGRAM
1	Top Slab = 0.2 x 24 x 1.4	6.72 KN/m²	
2	Super Imposed Earth Fill = 0.6 x 18 x 1.6	17.28 KN/m²	
3	Live Load = 112.5/(4h²) x 1 wheel x 1.3 = 112.5/(4 x 0.6²) x 1 wheel x 1.3	101.56 KN/m²	
4	Lateral Earth Pressure = (0.33 x 18 x 1.4)1.6	13.306 KN/m²	
5	Earth Surcharge Load = (0.33 x 18 x 0.6)1.6	5.702 KN/m²	
6	Live Load Surcharge = (0.33 x 10)1.6	5.28 KN/m²	
7	Water in Cell = (9.81 x 1.2)1.6	18.84 KN/m²	p3
8	Dead Load Of Walls 2 x (0.2 x 1.2 x 24) x 1.4/1.4	11.52 KN/m²	

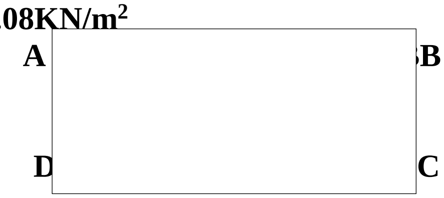
Case 1 - Culvert Empty **CHECK PRESSURE ON SOIL**		
ELEMENTS	NOMINAL LOAD	SERCICE LOAD
TOP + BOTTOM SLAB	2(0.2 x 1.4 x 24) x 1.0	13.44
The 2 Walls	2(0.2 x 1.4 x 24) x 1.0	13.44
Super Imposed Earth Fill	(0.6 x 1.4 x 18) x 1.0	15.12
Live Load	112.5/(4h²) x 1 wheel x 1 = 112.5/(4 x 0.6²) x 1 wheel x 1	78.125

REF	CALCULATION	OUTPUT
	Total service load = 120.125 KN/m Pressure exerted on the ground=120.12/1.4= 85.80KN/m 85.80KN/m² < 100KN/m² (i.e 100KN/m² is the Soil Bearing Capacity) **1 + 2 + 3 = 125.56KN/m²**	OK



10.982 KN/m² **13.31 KN/m²**

1 + 2 + 3 + 8 =137.08KN/m²



Onyenuga - 2008

$FEM_{CD} = -WL^2/12 = -137.083 \times 1.4^2/12 = -22.39KNm$

$FEM_{DC} = WL^2/12 = 137.083 \times 1.4^2/12 = 22.39KNm$

$FEM_{DA} = FEM_{CB} = -WL^2/12 - WL^2/20$
$= -10.982 \times 1.4^2/12 – 13.306 \times 1.4^2/20 = -3.10KNm$

$FEM_{AD} = FEM_{BC} = WL^2/12 + WL^2/30$
$= 10.982 \times 1.4^2/12 + 13.306 \times 1.4^2/30 = 2.66KNm$

$FEM_{AB} = -WL^2/12 = -125.563 \times 1.4^2/12 = -20.51KNm$

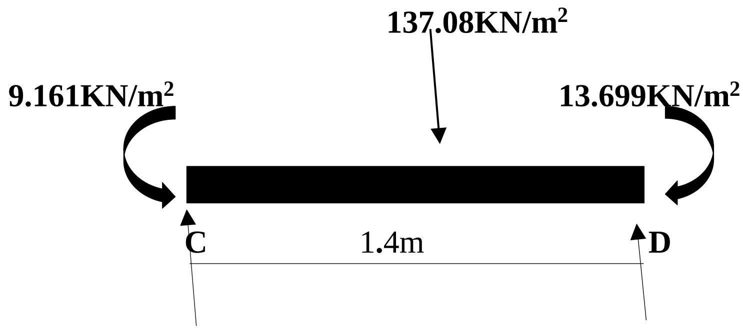
$FEM_{BA} = WL^2/12 = 125.563 \times 1.4^2/12 = 20.51KNm$

Due to the uniform second moment of area, the stiffness will be 1/1.4 and 1/1.14 or 0.5 and 0.5 for the wall and slab respectively.
Uniform Hard-cross method of Moment Distribution

JOINT	A		B		C		D	
Member	AD	AB	BA	BC	CB	CD	DC	DA
DF	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
FEM	2.66	-20.51	20.51	2.66	-3.10	-22.39	22.39	-3.10
BAL	8.923	8.923	-11.586	-11.586	12.744	12.744	-9.646	-9.646
CO	-4.823	-5.793	4.461	6.372	-5.793	-4.823	6.372	4.461
BAL	5.308	5.308	-5.471	-5.471	5.308	5.308	-5.471	-5.471
CO	-2.708	-2.708	2.654	2.654	-2.708	-2.708	2.654	2.654
BAL	2.708	2.708	-2.654	-2.654	2.708	2.708	-2.654	-2.654
CO	-1.327	-1.327	1.354	1.354	-1.327	-1.327	1.354	1.354
BAL	1.327	1.327	-1.354	-1.354	1.327	1.327	-1.354	-1.354

Total	12.1	-12.1	7.967	-7.967	9.161	-9.161	13.70	-13.70

SPAN CD



MOMENT ABOUT SUPPORT (D)

$1.4R_C – 9.161 - 137.08(1.4^2/2) + 13.699 = 0$

$1.4R_C = 9.61 + 137.08(1.4^2/2) - 13.699$

$R_C = 92.716$ KN

$R_D = (1.4 \times 137.08) – 94.675$

$R_D = 99.199$ KN

Position of maximum moment (DC)

$$\frac{X}{92.716} - \frac{1.4 - X}{99.199}$$

$99.199X – 92.716(1.4 – X)$

$99.199X + 92.716X = 129.803$

$$X = \frac{129.803}{191.92} = 0.676m$$

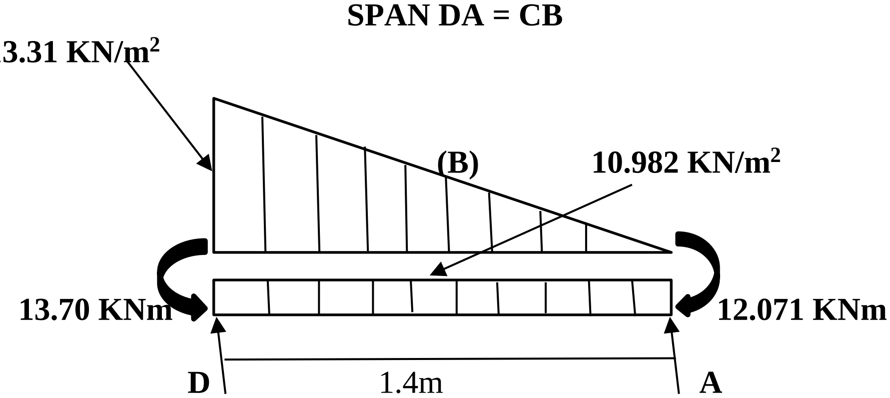
M_{max} for Span CD = $0.676R_c – 9.161 – 137.083(\{0.676^2\}/2)$

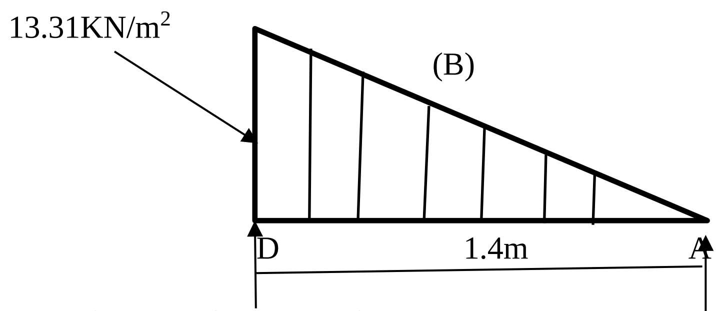
$= 92.716(0.676) – 9.161 – 31.355 = 22.193$ KNm

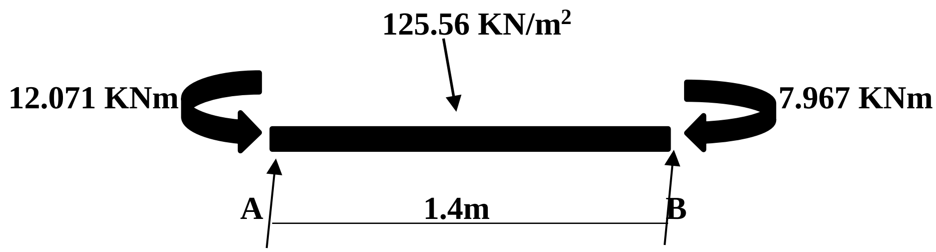
$R_C = 92.716$ KN

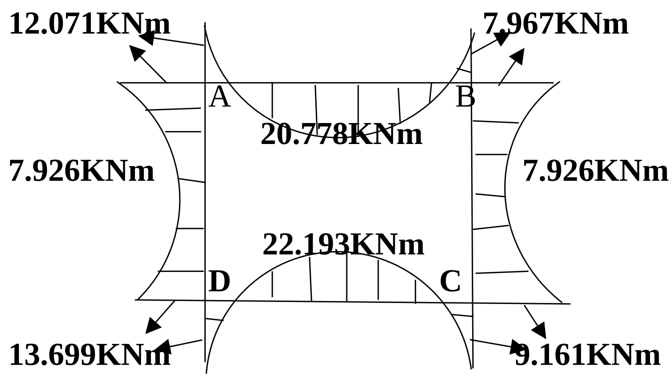
$R_D = 99.199$ KN

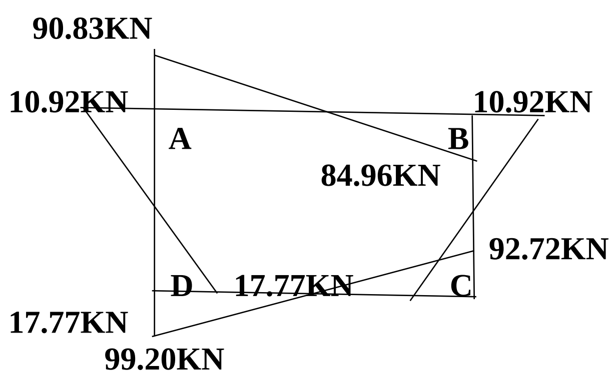
SPAN DA = CB



	Taking Moment about support (A) with load A only $1.4R_{D1} + 12.071 - 10.982(1.4^2/2) – 13.699 = 0$ $1.4R_{D1} = -12.\ 071 + 10.76 + 13.699$ $R_{D1} = 8.85$ KN	R_{D1}=8.85KN
	$R_{A1} = -R_{D1} + 10.982(1.4)$ $R_{A1} = -8.85 + 15.3748$ $R_{A1} = 6.52$ KN	R_{A1}=6.52KN
	Taking Moment about support A with load (B) only  	
	$R_{D2} = 0.67W = 0.67 \times 13.306 =$ 8.91 KN $R_{A2} = 0.33W = 0.33 \times 13.306 =$ 4.39085 KN	R_{D2} =8.89KN R_{A2}=4.39KN
	Total Reactions $R_D = R_{D1} + R_{D2} = 8.85 + 6.24 =$ 17.77 KN $R_A = R_{A1} + R_{A2} = 6.52 + 3.07 =$ 10.92 KN	R_D=17.77KN R_A=10.92KN
	POSITION OF M_{MAX} IN SPAN DA IE POSITION OF M_{MAX} FROM D $$\frac{X}{17.77} = \frac{1.4 - X}{19.92}$$ $10.92X = 17.77(1.4 – X)$ $10.92X + 17.77X = 24.8719$ $$X = \frac{24.8719}{28.681} = \quad 0.867m$$	
	POSITION OF M_{MAX} FROM A $M_{MAX} = 0.867R_A – 12.071 – 10.982(0.867^2/2) – 13.306/1.4 \times 0.867^2/2 \times 3$ $0.867(10.92) – 12.071 – 4.130 – 1.191 = -7.926$ KNm	M_{MAX} = - 7.926 KNm

	SPAN AB  **MOMENT ABOUT SUPPORT B** $1.4R_A + 7.967 - 12.071 – 125.56(1.4^2/2) = 0$ $1.4R_A = -7.967 + 12.071 + 123.05$ $R_A =$ 90.825 KN $R_B = -90.825 + 125.56(1.4)$ $R_B =$ 84.963 KN **POSITION OF M_{MAX} IN SPAN DC** $$\frac{X}{90.83} = \frac{1.4 - X}{84.963}$$ $84.963X = 90.825(1.4 – X)$ $84.963X + 90.825X = 127.155$ $$X = \frac{127.155}{175.79} = 0.723m$$ M_{MAX} for span AB $= 0.723R_A - 12.071 – 125.563(0.723^2/2)$ $= 0.723(90.825) – 12.071 – 32.818$ $M_{MAX} =$ 20.778KNm	R_A=90.83KN R_B=84.96KN M_{MAX} = 20.778KNm





Case 2 – (CULVERT FILLED WITH WATER)

Check pressure on soil foundation

ELEMENTS	**NOMINAL LOAD**	**SERVICE LOAD**
Top + Bottom Slab	2(0.2 x 1.4 x 24) x 1.0	13.44KN/m
The Two Walls	2(0.2 x 1.4 x 24) x 1.0	13.44KN/m
Super Imposed Earth Fill	(0.6 x 1.4 x 18) x 1.0	15.12KN/m
Live Load	112.5/(4h^2) x 1 wheel x 1 = 112.5/(4 x0.6^2) x 1 wheel x1	78.125KN/m
Water in Cell	9.81 x 1.4 x 1.4	19.23KN/m

Total service load = 139.35KN/m

Pressure exerted on the ground = 139.35/1.4 = 99.54KN/m^2

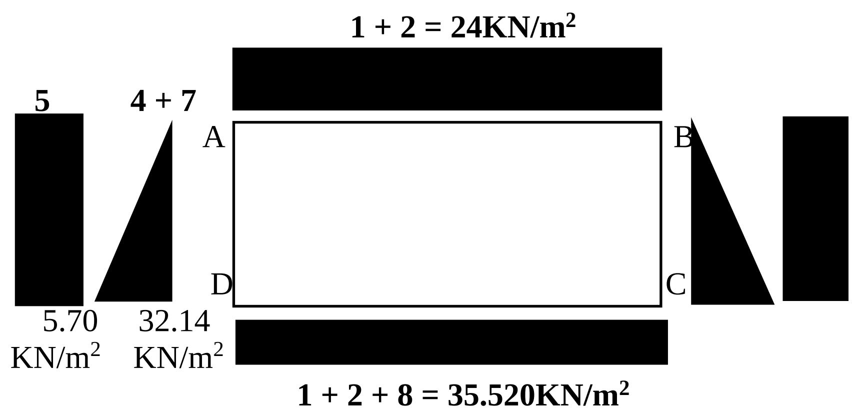
99.54KN/m^2 < 100KN/m^2

(i.e 100KN/m^2 is the Soil Bearing Capacity)

OK

LOADING FROM PRESSURE TABLE

Weight of water will not create bending moment although this weight is taken into account when calculating the maximum pressure on the ground.



FEM = $-WL^2/12 = -35.520 \times 1.4^2/12 =$ -5.80KNm

$FEM_{DC} = WL/12 = 137.083 \times 1.4/12 =$ 5.80KNm

$FEM_{DA} = FEM_{CB}$

$FEM_{DA} = -WL/12 - WL/20 =$

$FEM_{DA} = -5.702 \times 1.4/12 - 32.141 \times 1.4/20 =$ -4.08KNm

$FEM_{AD} = FEM_{BC}$

FEM_{AD} = WL/12 + WL/30 =
FEM_{AD} = 5.708 x 1.4/12 + 32.141/30 = 3.03KNm
FEM_{AB} = -WL/12 = -24 x 1.4/12 -3.92KNm

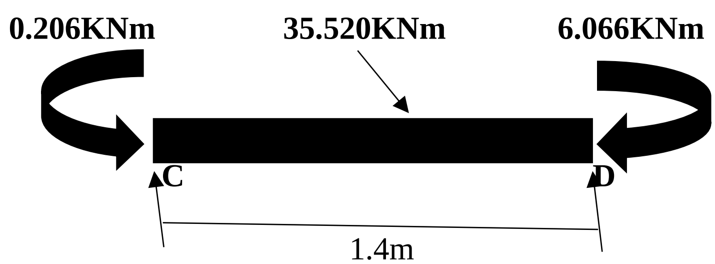
FEM_{BA} = WL/12 = 24 x 1.4/12 = 3.92KNm

Due to the uniform second moment of area, the stiffness will be 1/1.4 and 1/1.14 or 0.5 and 0.5 for the wall and slab respectively.

Using Hardy-Cross method of Distribution

Joint	A		B		C		D	
Member	**AD**	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DA**
DF	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
FEM	**3.03**	**-3.92**	**3.92**	**3.03**	**-4.08**	**-5.802**	**5.802**	**-4.08**
BAL	**0.444**	**0.444**	**-3.476**	**-3.476**	**4.941**	**4.941**	**-0.860**	**-0.860**
CO	**-0.43**	**-1.7378**	**0.222**	**2.471**	**-1.738**	**-0.430**	**2.471**	**-0.222**
BAL	**1.084**	**1.08396**	**-1.346**	**-1.346**	**1.084**	**1.084**	**-1.346**	**-1.134**
CO	**-0.673**	**-0.6732**	**0.542**	**0.542**	**-0.673**	**-0.673**	**0.542**	**0.542**
BAL	**0.673**	**0.6732**	**-0.542**	**-0.542**	**0.673**	**0.673**	**-0.542**	**-0.542**
CO	**-0.271**	**-0.271**	**0.337**	**0.337**	**-0.271**	**-0.271**	**0.337**	**0.337**
BAL	**0.271**	**-0.271**	**-0.337**	**-0.337**	**0.271**	**0.271**	**-0.337**	**-0.337**
Total	**4.13**	**-4.13**	**-0.680**	**0.680**	**0.206**	**-0.206**	**6.066**	**-6.066**

SPAN CD



MOMENT ABOUT SUPPORT D

$1.4R_C - 0.206 - 35.520(1.4^2/2) + 6.066 = 0$
$1.4R_C = 0.206 + 34.8096 - 6.066$
$R_C =$ 20.679KNm

R_C = 20.679 KN

$R_D = 35.520(1.4) - R_C$
$R_D = 49.728 - 20.697 =$ 29.045KNm

R_D = 29.045 KN

Position of Maximum Span Moment (DC)

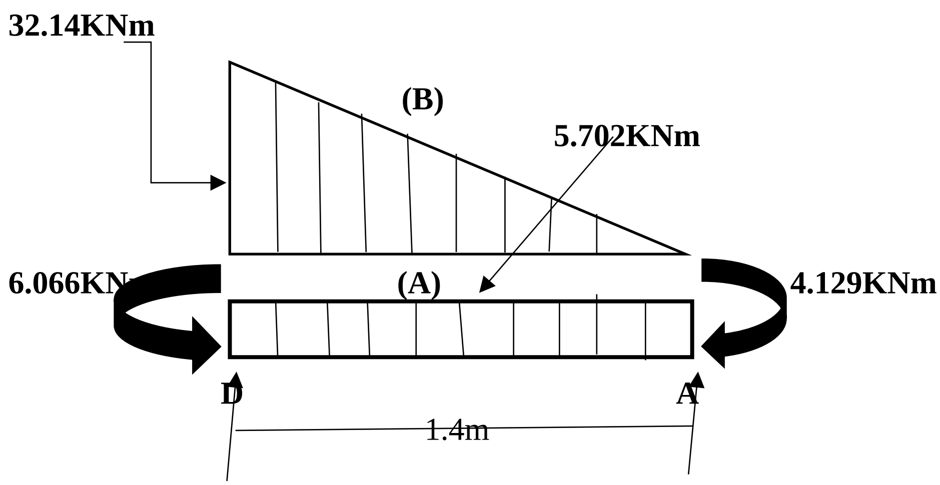
$$\frac{X}{20.679} = \frac{1.4 - X}{29.049}$$

$20.679(1.4 - X) = 29.049X$
$20.679X + 29.049X = 28.9503$

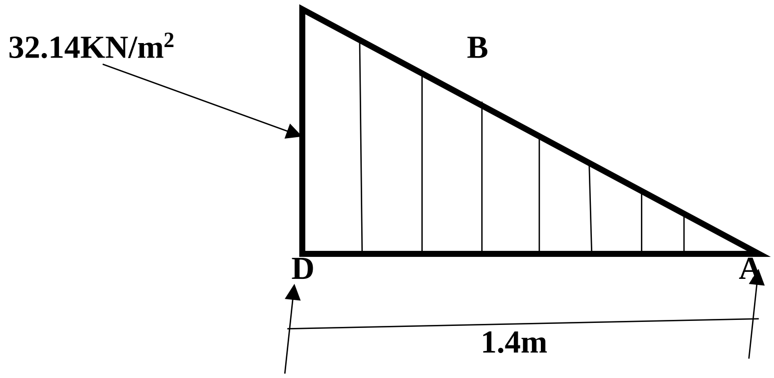
$$X = \frac{28.9503}{49.728} = \quad 0.582m$$

M_{MAX} for Span CD = $0.582R_C - 0.206 - 35.520(0.582^2/2)$
M_{MAX} for Span CD = 12.0352 – 0.206 – 6.0157= 5.813KNm

SPAN DA = CB



Taking Moment about Support (A) with load (A) ONLY
$1.4RD1 + 4.129 - 5.702(1.4^2/2) + 13.699$
$1.4R_{D1} = 4.129 + 5.588$ -6-066
$R_{D1} =$ -3.29KN
$R_{A1} = 5.702(1.4) - (-3.29KN) =$ 11.273KN
Taking Moment about Support (A) with Load (B) only



R_{D2} = 0.67W = 0.67 x 32.14 = 21.53KN
R_{A2} = 0.33W = 0.33 x 32.14 = 10.61KN

Total Reactions
$R_D = R_{D1} + R_{D2}$ = -3.29 + 21.53 = 18.24KN

$R_A = R_{A1} + R_{A2}$ = 11.27 + 10.61 = 21.88KN

R_D = 18.24KN
R_A = 21.88KN

Position of M_{MAX} in Span (DA) I.E. Position of M_{MAX} From D

$$\frac{X}{18.244} = \frac{1.4 - X}{21.880}$$

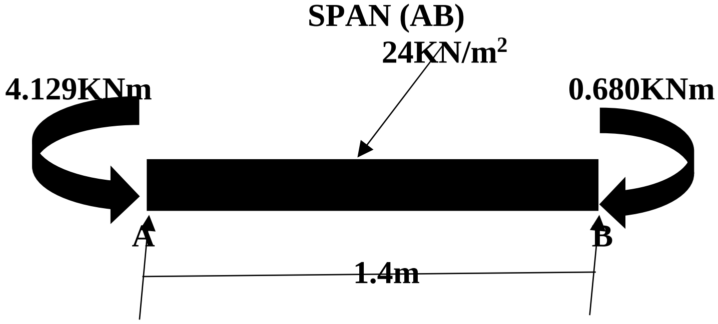
21.880X = 18.244(1.4 – X)
21.880X + 18.244X = 25.5413

$$X = \frac{24.5413}{40.124} = 0.637m$$

Position of M_{MAX} From (A)

$M_{MAX} = 0.637R_A – 4.129 – 5.702(0.637^2/2) – 32.141/1.4 \times 0.637^2/2 \times 3$
= 0.637(21.88) – 4.129 – 1.155 – 1.550
M_{MAX} = **7.093KNm**

SPAN (AB)



Moment About Support (B)

$1.4R_A + 7.967 – 12.071 – 125.563(1.4^2/2) = 0$
$1.4R_A = 4.129 + 23.520 – 0.680$
$R_A =$ 19.264KN
$R_B = (1.4 \times 24) – 19.264 =$ 14.336KN

Position of Max. Moment Span (DC)

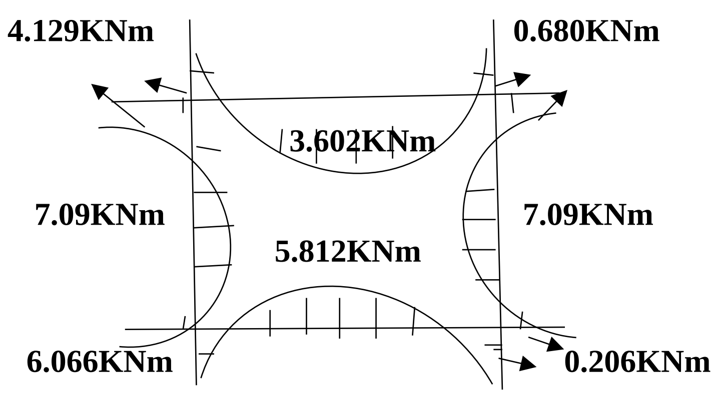
$$\frac{X}{19.264} = \frac{1.4 - X}{14.336}$$

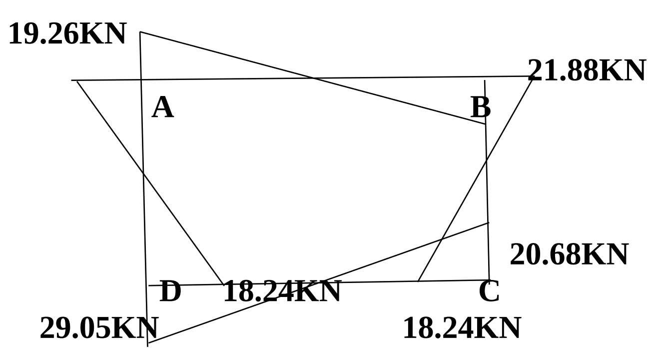
$14.336X = 19.264(1.4 – X)$

$14.336X + 19.264X = 26.9696$

$$X = \frac{26.9696}{33.60} = \quad 0.803m$$

M_{MAX} for Span (AB) = $0.803R_A -4.129 – 24(0.803^2/2)$
$= 19.264(0.803) – 4.129 – 7.731$
$M_{MAX} =$ 3.602KNm





$R_A =$ 19.264KN
$R_B =$ 14.336KN

DESIGN IS BASED ON CASE 1

Because the condition yields a higher value for the bending moment and shear force, Case 1 analysis will be used for design.

Clause 5.1.4.2
Table 5,6,13

SECTION DESIGN

Assume slab thickness h 200mm
Concrete Cover c 50mm
Ø/2 = 16/2 8mm
Effective depth d = overall depth - Concrete Cover - Ø/2
d = 200 - 50 - 8 = 142mm

d = 142mm

BS 8110
Part 1 - 1985
Clause 3.4.4.4

DESIGN OF SUPPORTS

Mmax Support = 13.699 KNm
K = M/(bd²fcu)
= $13.699*10^6/(1000 \times 142^2 \times 25)$ = 0.0272
K = 0.0272 < 0.15
La = (0.5 + √0.25 - K/0.9)
= 0.5 + √0.25 - (0.0272/0.9) = 0.97
Use La = 0.95
Z = La x d = 0.95 x 142 = 134.9mm

$M*10^6$	b	D	d²	Fcu	K/0.9	√0.25-K/0.9	La	Z
13.699	1000	142	20164	25	0.03	0.469	0.97	134.9

As req. = M/(0.87 x fy x Z)
= $13.699*10^6/(0.87 \times 410 \times 134.9$ = 284.69 mm²

As req = 284.69mm²/m

Use Y16 @ 250mm 804mm²/m

As prov. = 804mm²/m

Mosley & Bungey - 1987

Distribution Reinforcement:
Min. Steel = 0.13%bh
As min. = (0.13/100) x 1000 x 200 = 260mm²/m
Use Y12 @ 300mm 377mm²/m

Asmin prov. = 377mm²/m

$M*10^6$	Fy	0.87 fy	Z	As req.	0.13 %	b	h	As min.
22.193	410	356.7	134.68	284.69	0.0013	1000	200	195

BS 8110 Part 1 - 1985
Clause 3.4.4.4

DESIGN OF SPAN

Mmax SPAN = 22.193 KNm
K = M/(bd²fcu)
= $22.193*10^6/(1000 \times 142^2 \times 25)$ 0.0440
K = 0.0440 < 0.15
La = (0.5 + √0.25 - K/0.9)

= (0.5 + √0.25 - (0.0440/0.9) = 0.95
La = 0.95
Z = La x d = 0.95 x 142 = 134.9mm

M*10 6	K	b	d²	Fcu	K/0.9	La	Z
22.193	0.044	1000	20164	25	0.4892	0.95	134.9

As req. = M/(0.87 x fy x Z)
= 22.193*10^6/(0.87 x 410 x 134.9) = 461.21mm²/m
Use Y16 @ 250mm 804 mm²/m

As req. = 461.21mm²/m

As prov. = 804mm²/m

Mosley & Bungey - 1987

Distribution Reinforcement:
Min. Steel = 0.13%bh
As min. = (0.13/100) x 1000 x 200 = 260mm/m²
Use Y12 @ 300mm 377mm²/m

Asmin prov. = 377mm²/m

Design of Wall
Max. Support Reaction (Nmax) = 99.20 x 2
Nmax. = 198.40 KN
Le = Lol = 1200/200 = 6 < 12
Hence the wall will be design as a short column
That is Axially Loaded
N = 0.4Fcub(h -2e)
Since e = M/N = 0
N = 0.4 x 2.5 x 1000 x (200 - 2 x0) 2000KN
N = 2000KN >>>> Nmax (which is 198.40 KN)
Hence norminal reinforcement required is the minimum
100AS/bh = 1
AS = bd/100 = (1000 x 200)/100 = 2000 mm²
For one face. = 2000/2 = 1000mm²
Use Y16 @ 200mm 1010mm²/m

AS prov. = 1010mm²/m

CP 110
Clause 3

DISTRIBUTION REINFORCEMENT
100AS/bh = 0.25 for high yield steel
AS = (0.25 x 1000 x 200)/100 = 500mm²
For one face, 500/2 = 250mm²
Use Y12 @ 300mm 377mm²/m

AS prov. = 377mm²/m

Summary of Box Culvert Design Analysis.

Maximum shear and bending moments that could be experienced due to wheel load, water, and Earth pressure were calculated for the culvert.

By taking into account the potential occurrence of the loads and pressures, the bending moment is determined. The culvert was generally built around these two assumptions:

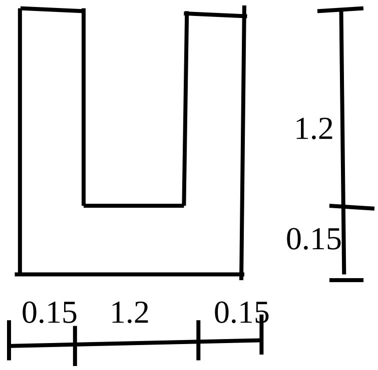
Case 1 Culvert Empty: Maximum earth pressure on the wall, weight of the walls, and full load and surcharge on the top slab.

Case 2: A culvert filled with water. The top slab is under the least amount of load, the walls are under the least amount of earth pressure, the walls are the heaviest, the culvert is under the most amount of horizontal pressure, and the top slab may experience some upward pressure. By considering these two conditions here, the maximum moment was adopted.

Due to the top slab's entire load and surcharge, the wall's weight, and the wall's maximum earth pressure, Case 1's circumstance provided the design with higher maximum moments and shear forces. The report's attachments include the structural information.

4.5 Bills of Engineering Measurements and Evaluation (BE ME) for Drainage

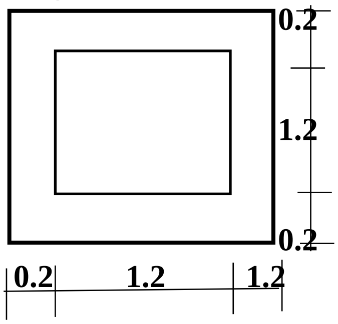
Typical BEME for 3500m x 1.2m x1.2m R.C DRAIN

S/N	Brief Description	No	L m	W m	D m	Unit	Qty	Rate ₦	Amount ₦
	3500m x 1.2m x 1.2m Reinforced Concrete Drain  L = 3500m Base width,W = 1.5m								
1.1.1	**BILL NO. 1: EARTH WORKS** Excavate foundation L = 3500m W = 1.2+(0.15 x 2)= 1.5m D = 1.2+0.15+0.05 = 1.4m		3500	1.5	1.4	m³	7350	150	1,102,500
1.2.1	Preparation of excavation surface L = 3500m W = 1.5m		3500	1.5		m²	5250	100	525,000
	BILL NO. 1 CARRIED TO SUMMARY								**1,627,500**
2.1.1	**BILL NO. 2: IN_SITU CONCRETE** Concrete Grade C10 L = 3500m W = 1.5m D = 0.05m		3500	1.5	0.05	m³	262.5	2000	525,000
2.2.1	Grade C25 Reinforced Concrete Base Base L = 3500m W = 1.5m D = 0.15m Walls L = 3500m		3500	1.5	0.15	m³	787.5 1260	10,000	7,875,000 25,200,000

	W = 1.2m D = 0.15m	2	3500	1.2	0.1 5	m³		20,000	
	BILL NO. 2 CARRIED TO SUMMARY								**38,325,000**
3.1.1	**BILL NO. 3: FORM WORK** Form work for side of Wall L = 3500m W = 1.2m	2	3500	1.2		m²	8,400	1500	12,600,000
	BILL NO. 3: CARRIED TO SUMMARY								**12,600,000**
4.1.1	**BILL NO. 4 REINFORCEMENT** Steel Reinforcement Total vol. of concrete = 2047.5m³ Steel Reinforcement = 71kg/m³ Qty in T = (2047.5 x 71)/1000 =					m³ T	2047.5 145.4	260,00 0	37,796,850
	BILL NO. 4 CARRIED TO SUMMARY								**37,796,850**
	SUMMARY **BILL NO. 1 : EARTH WORKS** **BILL NO. 2 : IN-SITU CONCRETE** **BILL.NO. 3 : FORM WORK** **BILL NO. 4: REINFORCEMENT**								**1,627,500** **38,325,000** **12,600,000** **37,804,000**
	GRAND TOTAL								**90,349,350**

4.6. Bill of Engineering Measurements and Evaluation (BEME) for Single Cell Box Culvert

BEME FOR 7.6m x 1.2m x 1.2m SINGLE CELL BOX CULVERT

S/N	**Brief Description**	**No**	**L** **m**	**W** **m**	**D** **m**	**Unit**	**Qty**	**Rate** **₦**	**Amount** **₦**
	7.6m x 1.2m x 1.2m x Single Cell Box Culvert 								
1.1.1	**BILL NO. 1: PRELIMINARY CARRIRED TO SUMMARY** **(**Preliminaries)								**600,000**
2.1.1	**BILL NO. 2: DEMOLITION AND SITE CLEARANCE CARRIED TO SUMMARY (**General Clearance)		7.6	1.6		m²	12.16	1500	**18,240**
3.1.1	**BILL NO. 3: EARTH WORKS** Excavate foundation Preparation of excavation surface **BILL NO. 3: EARTH WORKS CARRIED TO SUMMARY**		7.6 7.6	1.6 1.6	1.6	m³ m²	19.456 12.16	1500 200	29,184 2,432 **31,616**
4.1.1	**BILL NO. 4: IN-SITU CONCRETE** Provision and placing of concrete, design mix, cement to BS 12 Grade C10,mass binding, 40mm maximum aggregate Grade C25, reinforced, 20mm maximum	 2	7.6 7.6 7.6 7.6	1.6 1.6 0.2 1.6	0.05 0.2 1.2 0.2	m³ m³ m³ m³	0.608 2.432 3.648 2.432	3000 60000 60000 60000	1,824 145,920 218,880 145,920

	aggregate, in Culvert base, wall, slab Slab Walls Base **BILL NO. 4: IN-SITU CON. CARRIED TO SUMMARY**								**512,544**
5.1.1	**BILL NO. 5: FORM WORK** Form work Slab Wall **BILL NO. 5: FORM WORK CARRIED TO SUMMARY**	 2	7.6 7.6	1.6	0.2 1.2	m³ m²	2.432 18.24	3000 3000	7,296 54,720 **62,016**
6.1.1	**BILL NO. 6: REINFORCEMENT** Deformed high yield steel bars to BS 4449, nominal sizes, 12, 16 Total Volume of concrete= 8.512m³ Steel reinforcement = 246kg/m³ Qty in T= (8.512 x 246)/1000 **BILL NO. 6: REINFORCEMENT CARRIED TO SUMMARY**					m³ T	8.512 2	 260,000	**544,428**
	SUMMARY **BILL NO. 1: PRELIMINARIES** **BILL NO. 2: DEMOLITION AND SITE CLEARANCE** **BILL NO.3: EARTH WORKS** **BILL NO. 4: IN-SITU CONCRETE** **BILL NO. 5: FORM WORK** **BILL NO. 6: REINFORCEMENT**								**600,000** **18,240** **31,616** **512,544** **62,016** **544,428**

	GRAND TOTAL								**1,768,844**

	BEME FOR THE PROJECT GRAND SUMMARY	
S/N	**Description**	**Amount #**
A	**BEME FOR 3500m x 1.2m x 1.2m R.C DRAIN** **BILL NO. 1: EARTH WORKS** **BILL NO. 2: IN-SITU CONCRETE** **BILL NO. 3: FORM WORK** **BILL NO. 4: REINFORCEMENT** **SUB TOTAL BILL FOR ONE SIDE DRAIN**	 **1,627,500** **38,325,000** **12,600,000** **37,796,850** **90,349,350**
1	**SUB TOTAL BILL FOR TWO SIDE DRAIN**	**180,698,700**
B	**BEME FOR 7.6m x 1.2m x 1.2m Single Cell Box Culvert** **BILL NO. 1: PRELIMINARIES** **BILL NO. 2: DEMOLITION AND SITE CLEARANCE** **BILL NO. 3: EARTH WORKS** **BILL NO. 4: IN-SITU CONCRETE** **BILL NO. 5: FORM WORK** **BILL NO. 6: REINFORCEMENT**	 **600,000** **18,240** **31,616** **512,544** **62,016** **544,428**
2	**SUB TOTAL FOR THE CULVERT**	**1,768,844**
3	**SUB TOTAL BILL FOR TWO SIDE DRAIN +SUB TOTAL FOR THE CULVERT**	**182,467,544**
4	**CONTINGENCY (10%)**	**18,246,754**
5	**SUB TOTAL BILL FOR TWO SIDE DRAIN + SUB TOTAL FOR THE CULVERT + CONTINGENCY**	**200,714,298**
	Vat (5%)	**10,035,714**
	GRAND SUMMARY CARRIED TO FORM OF TENDER	**210,750,012**

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This initiative targeted issues with surface drainage along the Enugu-Onitsha Expressway (from Awkuzu to Amawbia Flyover Junction), The conclusions below were arrived at using the analysis and design. It is common known that a good drainage system is essential to the creation of an effective road network system. The main issue that sparked this study was how, due to an insufficient drainage system, water disrupted traffic during a heavy downpour and affected the condition of the road surface along the Enugu-Onitsha express road (from Awkuzu to Amawbia Flyover Junction), resulting in damage to the pavement and creating an unhealthy environment. As a result, the issue has become a burden for the locals, and the government must act quickly to address it.

The Enugu-Onitsha express road's drainage systems, which run from Awkuzu Park to the Amawbia Flyover Junction, were determined to be insufficient for draining rainwater. Additionally, because inhabitants regularly throw waste of all kinds into surface drains and culverts, they frequently remain blocked. Therefore, the road pavements suffer serious damage from standing rainfall. Water is forced to penetrate or seep into the pavement from the sides as well as the top surface due to poor drainage, especially during rainy seasons. As the top layers of the pavement separate from the bottom layers in the case of an open graded bituminous layer, this phenomenon becomes increasingly hazardous.

It was discovered that inappropriate road geometry, inadequate drainage structure capacity, subpar design and construction, and improper maintenance were the most frequent causes of road drainage issues. The upkeep of the current drainage systems was also determined to be lacking. In order to somewhat lessen the effects of water, particularly during rainy seasons, it is necessary to maintain the current drainage infrastructure. Inadequate drainage along the Enugu-Onitsha express road (from Awkuzu to the Amawbia Flyover Junction) has had a variety of far-reaching effects on the local community, the locals, and the road users. Following an inspection and thorough practical examination of the entire road, numerous issues were found, including potholes, water logging, ruts, and erosion on certain areas of the surface along the Enugu-Onitsha express road. (from Awkuzu to Amawbia Flyover Junction). Inadequate feasibility studies to determine the road's drainage requirements, inadequate drainage design, shoddy construction, and a lack of sufficient funding for drainage system upkeep are some of the causes of insufficient drainage systems. The drainage structures were revised based on two scenarios: when the drainage and culverts were empty and acting under the influence of earth pressure, and when they were full and under the influence of water pressure.

In contrast to the design moments calculated for the box culverts, which were 13.699KNm, 22.193KNm, and 99.20KNm for the support, span, and walls correspondingly, the design moments for the side drains were 5.48KNm and 5.38KNm for the walls and base, respectively. The BEME (Bill of Engineering Measurement and Evaluation) for the project was created, and it was determined that N210,750,012 would be the draft final estimated total cost for the building of the planned drainage structures.

A drainage and culvert is an appropriate and workable solution to the accessibility issue along the Enugu-Onitsha express road, according to analysis and design of the drainage and culvert. (from Awkuzu junction to Amawbia flyover junction).

5.2 Recommendations

The recommendations that were made were as follows in light of the findings of this research and design;

1. Road authorities should think about allocating a specific budget each year for drainage maintenance, drainage enhancement, and drainage and culvert maintenance and repair. Additionally, they ought to try to hire drainage inspectors who would keep an eye on and document any necessary drainage repair tasks.

2. The surface drainage system needs to be cleaned regularly. Open drains and culverts need to be cleaned out manually or using a machine. Additionally, it is necessary to clean and maintain any existing drain inlets and outlets.

3. The deplorable section of the road should be quickly rebuilt by the federal government in order to improve the situation for local residents and commuters.

4. In order to maintain the necessary crown and longitudinal slopes, proper road geometry must be maintained. This will shorten the water's drainage paths and avoid flow buildup as it flows over the pavement.

5. Regular maintenance calls for the provision of appropriate connections or integrations between the road and drainage systems.

6. As part of the routine maintenance program, deficiencies in road drainage should be noted and prioritized. Any problems in road drainage that need to be fixed must be done before or concurrently with any repair treatments being performed on road pavements.

REFERENCES

Amit, K.D. (2016). Drainage System of Highways. A Term Paper in Transportation Engineering. Lovely Professional University. Puniab-india. [Online] Accessed from https://www.scribd.com/doc/42527504/Drainage-System-in-Highways. Accessed on 11/05/2023.

Anisha, N.F. and Hossain, S.A. (2014). Case Study on Water Logging Problems in An Urban Area of Bangladesh and Probable Analytical Solutions, Proceedings of 2nd International Conference on Advances in Civil Engineering 2014(ICACE-2014), 26 - 28, Cute, Chattangong, Bangladesh.

Awka Climate Data (2018). [Online] Accessed from https://en.climate-data.org/location/46675/ Accessed on 02/5/2023.

Ayoade, J.O. (1974). Statistical Analysis of Rainfall over Nigeria. *Journal of Tropical Geography*, pp 11-23.

British Standard (BS) Code of Practice; BS 8110, Structural Use of Concrete, Part 1, 2, 3: 1997, Code of Practice for Design and Construction.

British Standard (BS) Code of Practice; BS8110, (1997). Structural Use of Concrete.

British Standard (BS) Code of Practice; BS5400. Steel, Concrete and Composite Bridges. PART 1: (1988) General Statement, Part 2: (1978) Specification for Loads, Part 4: (1990) Code of Practice for Design of Concrete Bridges.

Carluer, N. and De Marsily, G. D., (2004). Assessment and Modelling of the Influence of Man-made Network on the Hydrology of a small Watershed Implication for Fast Flow Components, *Water Quality and Landscape Management Journal of Hydrology*, **285**, (1), pp. 76-95.

Chow, V. T. Open Channel Hydraulic

Civil Engineering Dictionary (2014).

Collier, J. (2000), Storm Water Drainage Manual Wanchi, Hong Kong: Drainage Services Department, 43/F Revenue Tower, Sgloucester Road.

Design of Road Side Drainage System. [Online] https://www.scribd.com/presentation/396542993/Design-of-Road-Side-Drainage-System-Ppt.

Dipanjan M. (2014). Highway Surface Drainage System and Problems of Water Logging in Road Section. *The International Journal of Engineering and Science (IJES),* **3**(11), 44-51.

Diyoke, I.O.(2016). Draft Final Design Report, Elu Amuka Gully Erosion Mitigation Works, Diyoke Consultans Limited JV, Enugu Nigeria.

ERA Design Manual (2013)

Final Drainage Design Project. [Online] Accessed from https:// www.Scribd.com/doc/30203062/Final-Drainage-Design-Project. Accessed on 22/4/2023.

Kolade, A. (2022). Design of Rectangular Road Side Drains / Drainage Sewers and Channel, [Online] https://structville.com/design-of-rectangular-roadside-drains.

Kwihk, Final Drainage Design Project uploaded. [Online] Accessed from https://www.scribd.com/doc/30203062/Final-Drainage-Design-Project.

Ministry of Works Design Manual on Drainage.

Mosley, W.H. and Bungey, J. H. (1987). Reinforced Concrete Design, Fourth Edition MacmillanPress Ltd.

Muhammad, B.B. (2014), Highway Drainage System [Online]. Accessed from https://www.linkedin.com/pulse/201411250452545392-highway-drainage-system.

O'Flaherty, C. A (2002). Surface Drainage for Roads. Chapter 7, Highways, 4th Ed., Butterworth-Heinemann, Oxford, UK, pp. 185-209.

Paul, D. L. (1996). Practical Research: Planning and Designing, 12th Edition, Pearson International, NY.

Oyenuga, V. O. (2011). Reinforced Concrete Design. Second Edition. Asros limited, Lagos, Nigeria.

Rathi, M. K. and Rajiv, P. D. (2011). Study of Problems and Corrective Action of Urban Drainage Network, Preceding of International Conference on Electric Technology and Civil Engineering (ICETCE), 22 - 24, Lushan, China, pp. 1561 - 1564.

Reynolds, C.E. and Steedman, J.C. (1999). Reinforced Concrete Designer's Handbook, 10th edition. E & FN Spon, Taylor & Francis Group 11 New Fetter Lane, Location. UK.

Rottier, E. and Ince, M.E(2003). Controlling and Preventing Diseases: The Role of Water and Environmental Sanitation Inventions. WED goat Annexe b: Designing a Simple Drainage System for Storm Water. WEDC Publications, Loughborough University, UK.

T.F.FWA. (2006), the Handbook of Highway Engineering CRC Press 2006.

Washington State Department of Transportation, Environmental and Engineering Service Centre, Hydraulic Branch, (1997). Hydraulic Manual: Washington State Department of Transport **23**(3).

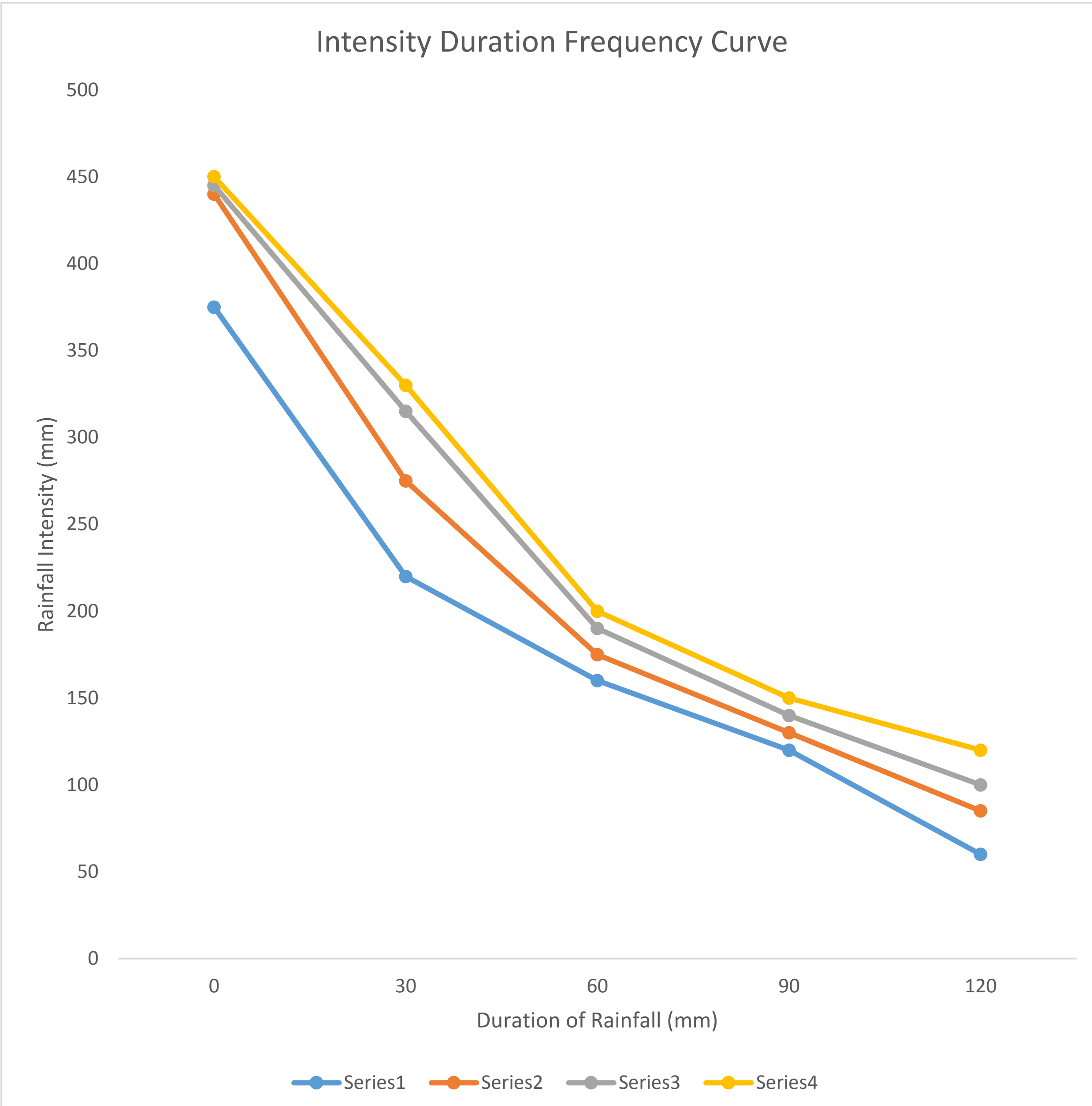
Washington D.C. (1992). Highway Drainage Guideline.

Wigan, J.M. (1970), Peak Flow Rainfall Events, in Gray, D.M., Ed., Handbook on principles of Hydrology: Port Washington, New York, Water Information Centrer, Inc. 102p.

US Forest Service, (2014), Highway Drainage Design.

Wyatt, (2000), Road Drainage Design: An Online PDH Course by CEDenginerring.com.

APPENDIX A



INTENSITY DURATION FREQUENCY (IDF) curve to Awka.

Source: National Geo hazard Monitoring Center, Awka.

APPENDIX B

Runoff coefficient values for urban areas

Pavement and Roof	0.90	0.90	0.90
Earth Shoulders	0.50	0.50	0.50
Drives and Walks	0.75	0.80	0.85
Gravel Pavement	0.50	0.55	0.60
City Business Areas	0.80	0.85	0.85
Apartment Dwelling Areas	0.50	0.60	0.70
Normal Residential Areas	0.40	0.50	0.55
Dense Residential Areas	0.50	0.65	0.70
Lawn Sandy Soil Areas	0.10	0.15	0.20
Grass Shoulders	0.25	0.25	0.25
Side Turfed Slopes	0.30	0.30	0.30
Cultivated Land (Clay and Loam)	0.50	0.55	0.60
Cultivated Land (Sand and Gravel)	0.25	0.30	0.35
Industrial Areas	0.50	0.70	0.80
Parks and Cemeteries	0.10	0.15	0.20
Play Ground	0.20	0.25	0.30
Woodlands and Forests	0.10	0.15	0.20
Meadows and Pasture Land	0.25	0.30	0.35
Unimproved Areas	0.10	0.30	0.30
Source: Federal Republic of Nigeria Highway Manual Part 1 Drainage Design			

APPENDIX C

Frequency Periods of Storm Sewers for Differential

Areas	Frequency Periods (years)
Residential Areas	2 - 10
Commercial and High value district	10 – 50
Flood Protection Works	50
Urban Roads	5
Source: Federal Republic of Nigeria Highway Manual Part 1.	

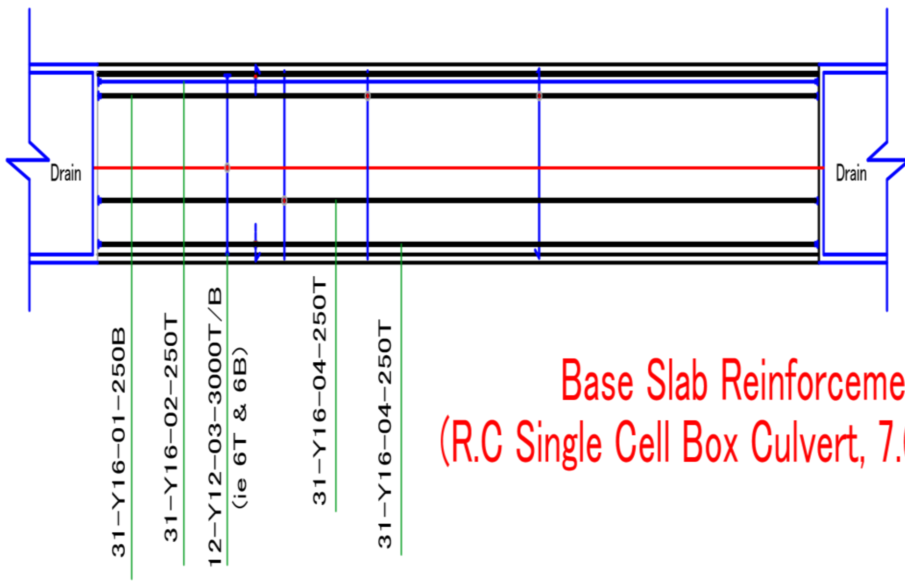
APPENDIX D

Manning's Coefficient (Public Health and Environmental Organization, 1990)

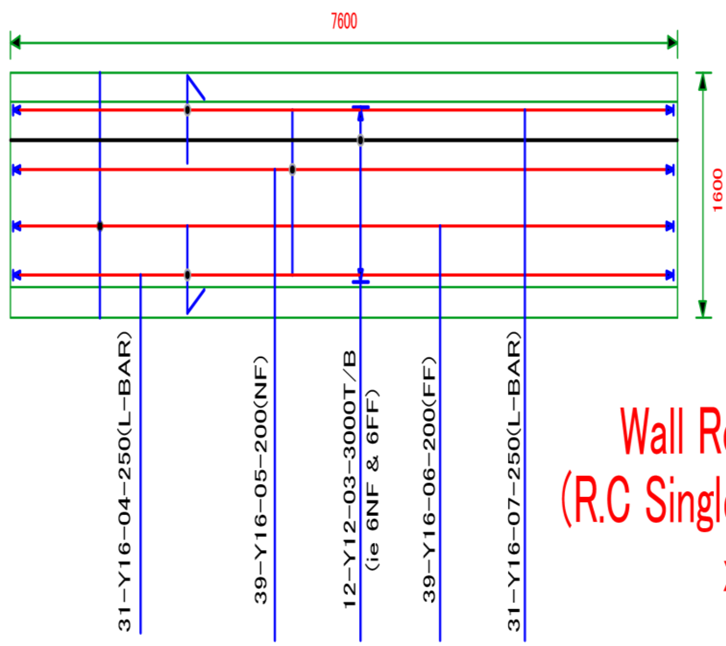
SURFACE	**Condition**			
	Best	Good	Fair	Bad
Concrete Lined Channels	0.012	0.014	0.015	0.018
Cement Rubble Surface	0.017	0.025	0.025	0.030
Dry Rubble Surface	0.025	0.030	0.033	0.035
Cement Motor Surface	0.011	0.012	0.013	0.015
Brick Sewers	0.012	0.013	0.015	0.017

Plate 1: Field measurements of the dimensions of the Culvert along Enugu-Onitsha Expressway.

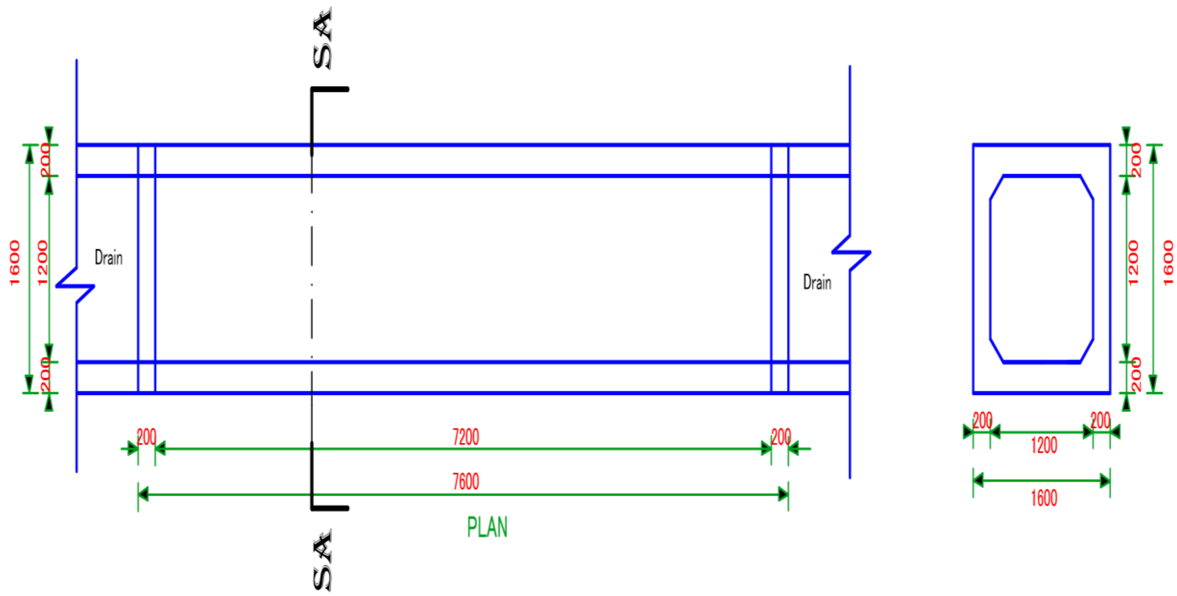
Plate 2: Field measurements of the dimensions of the Drain along Enugu-Onitsha Expressway.

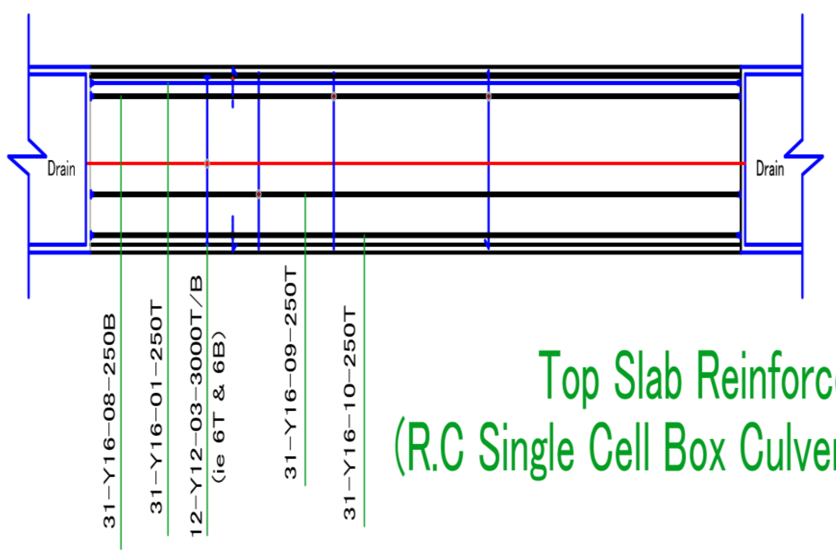


Base Slab Reinforcement Details
(R.C Single Cell Box Culvert, 7.6m x 1.2m x 1.2m)

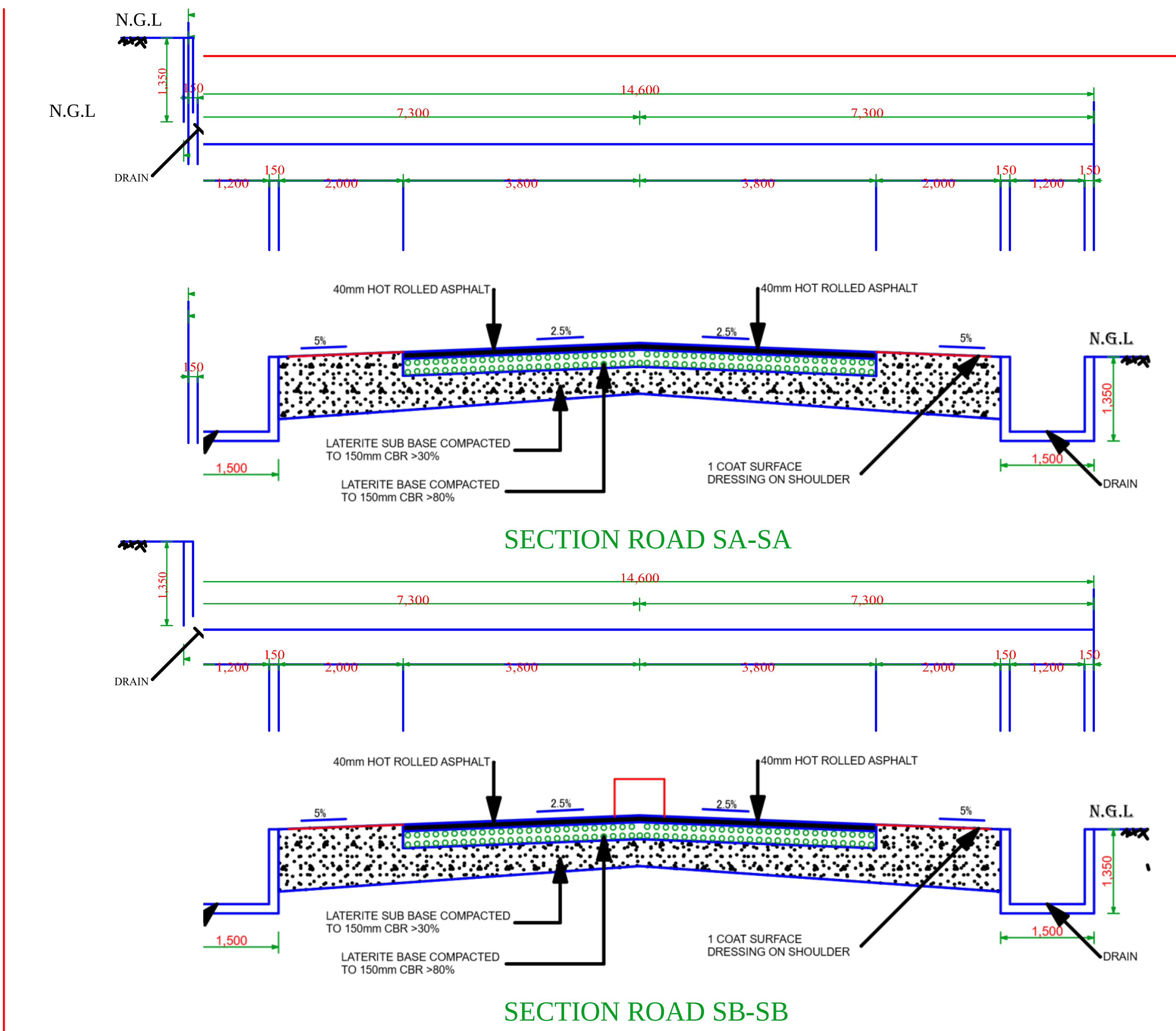


Wall Reinforcement Details
(R.C Single Cell Box Culvert, 7.6m x 1.2m x 1.2m)





Top Slab Reinforcement Details
(R.C Single Cell Box Culvert, 7.6m x 1.2m x 1.2m)



Department of Civil Engineering
Faculty of Engineering
Nnamdi Azikiwe University, Awka

ANALYSIS AND DESIGN OF EFFICIENT DRAINAGE STRUCTURES FOR THE RECONSTRUCTION OF ENUGU-ONITSHA EXPRESS ROAD.

TITLE

CROSS SECTION OF THE ROAD

DRAWN ANUNOBI AUGUSTINE CHUKWUEBUKA
REG NO : 2017224065
CHECKED: REV. DR. CHIDOZIE MADU NWAK

DATE: MAY 2023