DESIGN OF AN UNDERGROUND UTILITY DUCT USING TRENCHES METHOD (CASE STUDY: KIMERA ROAD) TRENCHLESS METHOD

FINAL YEAR PROJECT REPORT

Submitted to

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For the degree of Bachelor of Science in Civil Engineering

BY

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DECLARATION

We bear true allegiance to the information contained in this final project on design of underground ducts across road pavement (KIMERA. ROAD) for utilities using trenchless method and solemnly affirm that the work is our own and has never been submitted to any academic institution for any award.

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APPROVAL

I hereby certify that this final project titled "Design of an underground duct across an existing road pavement for utilities using trenchless method has been prepared under my supervision.

Sign ....

Date ....

MR.WAFULA PETER

ACKNOWLEDGEMENT

With undying gratitude, we would like to thank the almighty God for enabling us complete this final year project successfully. With great respect, we would like to specifically appreciate Mr. Wafula Peter for the guidance during the preparation of this report.

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There is no specific and packaged way we can thank our parents for the solemnly sincere help granted at all times as per their capacity, both financial, motivation, time and materialistic assistance. Thank you please, may the almighty God bless you all. Lastly, our sincere appreciation and gratitude goes to all our friends.

Sincerely we cannot hesitate to say thanks for your contribution in different capacities.

God bless you with a bombardment of blessings.

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LIST OF ACRONYMS

KIU	:	Kampala International University
APWA	:	American Public Works Association.
CBR	:	California bearing ratio
AL	:	Atterberg limits
LL	:	Liquid Limit
LS	:	Linear Shrinkage
PI	:	Plasticity Index
PL	:	Plastic Limit
AASHTO	:	American Association of State Highways and Transport Officials.
BS	:	British Standards
AADT	:	Average Daily Traffic
ROW	:	Right-Of-Way
DCP	:	Dynamic Cone Penetrometer
AADT	:	Annual Average Daily Traffic
TRRL	:	Transport Road Research Laboratory

ABSTRACT

Trenchless construction is the use of construction methods to install and repair underground utility systems with minimum open cut excavation. This includes the use of pipe jacking, micro tunneling, horizontal direction drilling, and guided boring systems.

This was adopted to replace the aging utility infrastructure and install new facilities, while minimizing disruptions to traffic communities and business, reducing environmental impact and lowering the high costs of pavement removal and site restoration. Critical areas of a trenchless application include crossing of conduits beneath highways, streets, railroads and other transportation arteries.

Chapter one: Introduction which gives the general background of the study, statement of the problem, significance of the project, project objectives and scope of the project

Chapter two: Literature review, which reviews documents, related to the study topic.

Chapter three: Methodology which contains the primary and secondary data, quantitative and qualitative evaluations of trenchless method to the obtain best applicable Trenchless method to use for installation of the designed concrete duct and procedures how to install the duct.

Chapter four: results, discussions and findings obtained in the test results and traffic count.

Chapter five: challenges, the conclusions and recommendations.

CHAPTER ONE

1.0 Background

Utilities such as gas, water, and telecommunications are increasingly posing challenges in road construction with the greatest damaging impact on newly paved streets consequently reducing the roadway expected life of the pavements According to the department of public work city and county of San Francisco (1998), considerably due to the nature of utility cuts which more often have an underground passage. However, the need for the utility cuts continues to increase with desire to hide utility lines for reasons such as aesthetics, factors contributed as a result of weather, and safety purpose According to American Public Works Association (APWA 1997). Internationally, Jones (1999) reported that Utility cut restoration is the second cause of traffic disruptions and has a significant effect on pavement performance.

The three typical pavement patch failures occur within the first year or two after initial utility cut has been made and the pavement patch has been completed. These failures include pavement patch settling and failing. Pavement patch rising and pavement adjacent to the utility patch settling and failing. Studies have been conducted on utility cut repair techniques in a number of countries, which mainly dwelt on the improvement of backfill and trenching techniques and as a result, several remedial methods have been adopted basing on the following parameters; trench and trenchless excavations, backfill materials, compaction requirements and quality control and quality assurance as discussed in the literature.

In conclusion, this study will help to establish whether it is better to install an underground duct using trenchless method under an existing road pavement as compared to cutting across the pavement. The study will look at bridging the gaps in the system such as design of an underground duct to transmit utilities across the road.

1.1 Problem statement

Utility cuts made across road pavements to install utility services have led to early deterioration of road pavements. These utilities include water pipes, sewage pipes, telephone cables, electricity cables and optical fiber lines. When these cuts are restored, distresses especially potholes tend to start from the areas of weakness, the places around them settle resulting in uneven pavement surfaces which causes discomfort for the drivers and other vehicle occupants as seen in the figure1:1 below, thus the government spends a lot of money trying to maintain the road pavements. Therefore, there is need to come up with remedies to try and curb the problem.

FIGURE 1: 1 DEFECTS OF UTILITY CUT ON THE PAVEMENT

1.2 Main objective

To design an underground duct across an existing road pavement (Kimera road) for utilities.

1.3 Specific objectives

The following are the specific objectives of the study

- To carry out traffic assessment to determine the traffic class along Kimera Road.
- To investigate the geotechnical properties of the soils around the site of the proposed utility duct.
- To determine the required structural capacity for the utility duct to be designed.
- To design the duct basing on the devised Trenchless method of installation that is practical hence minimizing destruction to the existing road structure.

1.4 Project scope

The project involved traffic assessment, geological investigation, evaluating the best method of Trenchless installation, determining the structural capacity of the duct and design of the concrete duct.

1.4.1 Time scope

The project started in October 2018 and has ended in May 2019

1.4.2 Geographical scope

Kimera road covers a distance of 1.38km, which stretches from Ntinda road in central region division to Bukoto Ntinda road. The road is surrounded by stretcher road and semawata road as shown below.

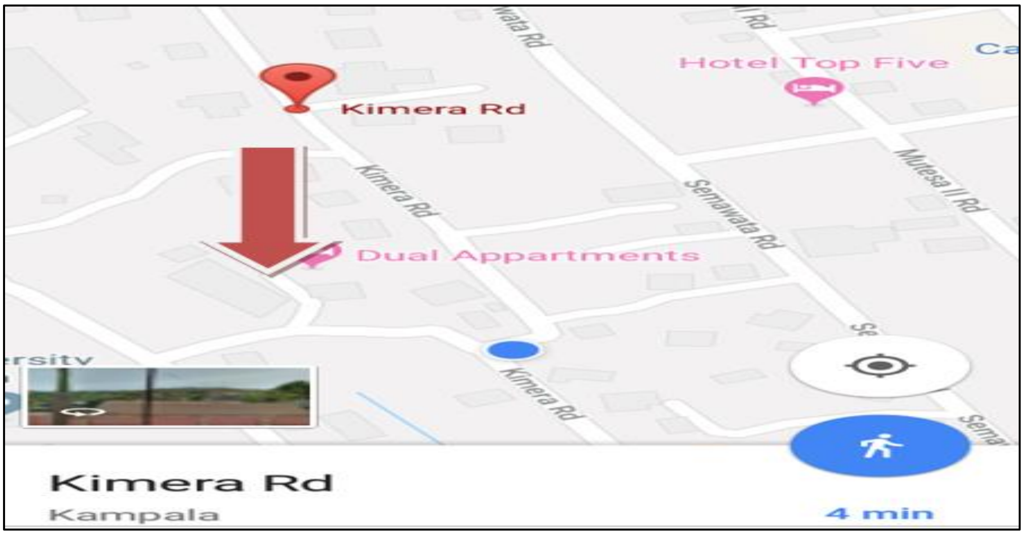

FIGURE 1: 2 LOCATION OF KIMERA ROAD FROM GOOGLE MAP.

1.4.3 Content scope

The project focused on the design of an underground duct across Kimera Road in Ntinda. It also involved looking at the design principles of ducts and recommending the best option to use as far as trenchless technology is concerned, all this was achieved after collection of data through surveying and soil testing.

1.5 Project significance

- The development of project will help to reduce on the early deterioration of the pavement performance that comes as a result of utility cut restorations
- The development of the project under trenchless technology will help in saving time due to the reduced traffic interruption during the process of installation of the utility duct.
- The development of the project will help to reduce on the government excess expenditure that a rise during the maintenance of the resulted defects on the pavement thus saving money for other economic activity development.

1.6 Project justification

There is great need to avert early deterioration of the utility cuts by using the trenchless technology. This will go a long way in saving the Government a lot of money in maintaining its road network more frequently than necessary as well as improving the driver’s comfort on the road networks. It will go a long way to prevent interruption to the traffic on that particular pavement. Moreover, huge amount of these funds comes from donor money and so, this further increases the debt burden of Uganda. This money could be used to develop other sectors of the economy like extending the road network to rural areas, modernizing agriculture, rural electrification and improving education facility.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Utilities such as gas, water, and telecommunications, and sanitary and storm sewers require an excavation for an installation of the pipes or lines. The number of utilities placed underground continues to increase with the desire to hide the utility lines for reasons such as aesthetics, factors contributed as a result of weather and safety purposes according to (APWA 1997) .Excavations normally takes place along road pavement. Once a cut is made, restoration is constructed, resulting on patched surface on a pavement. Cuts not only disturb the original pavements, but also the base course and the subgrade structure around the cuts. Once a utility is repaired and in place, the cut is backfilled, compacted and surfaced. If the backfill material is not suitable for the site conditions or not properly installed this material will begin to settle relative to the original pavement. According to the department of public work city and county of San Francisco (1998), utility cuts have the greatest damaging impact on newly paved streets, and therefore reduce the roadway expected life of these new pavements considerably. In some cities, millions of dollars are spent each year on maintenance and repairs of utility cuts and pavement (APWA 1997). With the continuing growth and need for repair of utilities this issue is becoming a large problem and further studies are needed to reduce the resulting damage.

Utility cut restoration has significant effect on pavement performance. It's often observed that the pavement within and around utility cuts fails prematurely, increasing maintenance costs. For instance, early distress in pavement may result in the formation of cracks were water can enter the base course. In turn leading to the deterioration of the pavement according to (Peters 2002). The resulting effect has a direct influence on the pavement life, aesthetic value, and drivers' safety according to (Arudi et al 2000). The magnitude of the effect depends upon the pavement patching procedures, backfill material conditions, and climate, traffic, and pavement conditions at the time of patching. According to Bodocsi et al. (1995) noted that new pavements should last between 15 and 20 years, however once a cut is made the pavement life is reduced to about 8 years. Furthermore, Tiewater (1997) indicts that several cuts in a roadway can lower the road life by 50%. Statistically data reported by the Department of public works in San Francisco (1998) show that the pavement condition rating decreases as the number of utility cuts made across increases. E.g., the pavement conditions score for a newly constructed pavement is reduced from 85 to 64 as the number of utility cuts increases to 10 or more for pavements less than 5 years.

2.2 Utility cut patching failures

Three pavement patch failures occur within the first year or two after the initial utility has been made and the pavement patch has been completed.

- The pavement patch settles resulting in vehicles hitting a low spot, as well as collection of moisture, which can induce additional settlement.
- The pavement patch rising forming "hump" over a utility cut area.
- The pavement adjacent to the utility patch starts settling and fails, leading in time-the patch itself to fail. This condition normally results when the natural soil adjacent to the utility trench and the overlying pavement section has been weakened by the utility excavations. This weakened zone around the utility cut excavations is called the zone of influence and extends laterally up to one meter around the trench perimeter according to the Department of Public Works City county of San Francisco 1998).

The causes of the three types of failures discussed above depends on factors such as quality and the type of restoration adopted, backfill materials used and their compaction, and the age and condition of the existing pavement before restoration.

2.3 Utility installation practices

These include the trench Backfill materials, compaction requirements, trenchless excavations and quality assurance basing on the research that has been conducted to improve these practices as discussed below.

2.3.1Trench

The size of excavations depends on, pipe diameter (in case of water transmission), compaction requirements, and the type of backfill material chosen, working space requirements and also varies from very narrow and confined to wide and open spaces. The maximum width value is determined by measurements corresponding to the bottom of the trench and if applicable, the area including sheeting and bracing (Polk County Public Works, 1999). The depth of the trench depends on factors such as location and slope needed for pipe installation or repair.

2.3.2 Back filling materials

The type of trench back fill material (i.e., Cohesive and non-cohesive) selected for restoration can impact future settlement. Cohesive clay type back fill materials require moisture control to reach maximum density, work experience, extensive compaction monitoring, and can be difficult to compact specifically in tight trenches. Granular native material with a high compacted density may be suitable as a backfill material. For many reasons such as those stated above, generally cohesion less granular materials are used as backfill materials can be compacted more easily (APWA 1997).

Generally, compaction of 95% maximum dry density using standard protor is required for backfill materials (APWA 1997).

2.3.3 Compaction equipment.

Using correct equipment for a project is important for achieving correct levels of specified compaction. The type of equipment used for a project may depend on factors such as the type of material, amount of compaction needed, amount of moisture the material contains, and availability of compaction equipment. APWA (1997) lists three types of compactors used for backfilling trenches (1) ramming, (2) static, and (3) vibratory. The vibratory method provides a more consistent compaction, but a limited amount of vibration should be used because excessive vibration can reverse its effect by loosening the soil. The vibrating plate is best used for granular materials because of its ability to lower friction between sand and gravel, therefore allowing both the machine and material weight to aid in compaction (jayawickramaet al.2000).

2.3.4 Quality control and assurance.

Quality control and assurance may be one of most important factors in a successful trench inspection, which should take place when work is in progress at the completion of the project and about one year from completion assuming that there is a warranty on the patch ending after one year.

New technology in reaching a specified backfill compaction standard is involving the use of dynamic cone penetrometer (DCP). From reviewing current practices, it has been noted that a variety of stages in the construction of a utility cut are critical and if not performed correctly can have effects that may cause a poorly performing restoration in future.

2.3.5 Permit fees.

Most cities in developed countries require a permit to be obtained before a cut can be made for a utility. The permit generally covers information such as administration, inspection, and fees dependent on the size of the cut (APWA 1997). Inspection fees, opening fees, and loss of structural integrity fees are being adapted in attempt to compensate for future maintenance costs (Arudiet al.2000). The purpose of the structural integrity fee is to require contractors to pay fee to cover repairs that are expected in the future, based on the amount of damage that is foreseen (Tie water 1997)

2.3.6 Trenchless Excavations (Technology).

Trenchless construction is the use of construction methods to install and repair underground utility systems without open cut excavation. This includes the use of pipe jacking, micro tunneling, horizontal direction drilling, and guided boring systems

This is adopted to replace the aging utility infrastructure and install new facilities, while minimizing disruptions to traffic communities and business, reducing environmental impact and lowering the high costs of pavement removal and site restoration. Critical areas of a trenchless application include crossing of conduits beneath highways, streets, rail roads and other transportation arteries. These conduits need to be implemented without the disruption to vehicular traffic and with minimal effects on the long-term integrity of the overlying structures or roads. The effect of trenchless on overlying roadways must be considered in design.

A quantification of soil loading mechanism would provide rational basis for pipe and conduit design. A better understanding of soil/pipe/machine interrelationship would permit improvements in the design and performance of trenchless equipment and installed pipes.

2.3.6.1 Methods of installation under trenchless technology

They are used to install cables and pipelines below the ground with minimal excavation. The methods include in details:

i. **Tunneling**

This simply refers to digging tunnel. It requires extensive investigation of ground conditions to enable proper choice of machinery, excavation methods and ground support. Temporary Bench Marks cannot be used for small diameter trenches.

ii. Micro tunneling

This is one is used to construct small tunnels mainly in sewer works. The micro tunnel-boring machine is operated remotely where the operator must be highly skilled and experienced to ensure accuracy in driving. A computer console is used to convey information about machine's orientation, location and hydraulic devices to the operator.

Pipe jacking is used to push tunnel liner behind the machine. Friction between the linear and the ground is minimized by cutting or using benonite slurry.

Advantages of micro Tunneling

- There is minimal disruption of traffic and low noise levels.
- The extent and duration of road occupancy is small when compared to trenched method of construction.
- Pre-cast concrete pipes may be jacked into place.

Disadvantages micro Tunneling

- Expensive machinery
- High level of skill required especially for the operator.
- There is need to construct a control container with a hoist to lower pipes into the drive shaft.
- Design resources are required to thoroughly investigate ground conditions and allow proper choice of cutting head for the machine to be used, as well as jacking forces and spoil removal system.

iii. Horizontal directional drilling

This method is used to install underground pipes, cables and conduits in a shadow arc along a prescribed bore path. A surface launched drilling rig is used and pipes are made of materials such as PVC, polyethylene, ductile iron, and steel.

It involves the following process: A pilot hole is first drilled. A larger cutting tool known as a back reamer then enlarges the hole and the casting pipe is placed in the enlarged hole. A Viscous drilling fluid (which is usually a mixture of water and bentonite or a polymer) is required to facilitate spoiler removal, stabilize the borehole, cool the cutting head and lubricate passage of the pipe. Directional capabilities enable the operator make necessary changes in direction of the cutting head.

Advantages of horizontal directional drilling

- There is minimal traffic disruption
- It's preferable in environmentally sensitive areas and congested areas.
- It has short completion times.
- It allows deeper and longer installation.

Disadvantages of horizontal direction drilling

- The operator does not have continuous feedback on the position of the cutting head; therefore, uncontrolled drilling may cause severe damage.
- The machinery is expensive
- High level of skill is required of the operator

iv. Pipe jacking

Hydraulic jacks are used to push specially made pipes through the ground behind a tunnel boring machines of shield. It is used to create tunnels under existing roads or railways.

Pipes in range of 150mm to 3000mm may be installed. Thrust and receiving pits should be constructed. The receiving pits are used to receive the shield at the end of each drive. A thrust ring is required to uniformly distribute the driving load from the hydraulic jacks. A thrust wall should be constructed to provide a reaction against which to jack. For accuracy of alignment, a steerable shield is used which must be frequently checked for line and level.

Advantages of pipe jacking

- It is applicable for a wide variety of ground conditions.
- The method provides flexible structural water tight finished pipeline as tunnel is excavated.

Disadvantages of pipe jacking

- Expensive machinery
- It's not cost effective for shallow installations

- It’s expensive to construct a thrust wall
- It has longer completion time because of necessary additional work items such as excavation for thrust and reception pits and construction of the thrust wall.
- It requires specially designed pipes.
- Highly skilled labor is required.

v. Pipe ramming

This is a trenchless method for installation of steel pipes and castings over distance usually up to 30m and up to 1.5m diameter. It is most applicable for shallow installations under roads and railways. It is a pneumatic method. The pipe is driven into the ground by pneumatic percussive blows. The leading edge of the pipe is always open ended. The shape is designed to allow a small overcut and minimize friction between the pipe and the soil, and direct the soil into the pipe rather than compacting it outside. (To achieve this, a soil cutting shoe or bands may be attached to the leading edge of the pipe). Further reduction of friction is through lubrication by bentonite or polymers.

Spoil removal is by augering, compressed air or water jetting. For shorter installations, spoil removal is usually done after installation of the pipe. But for longer installation or when a pipe with spoil becomes too heavy, the ramming may be interrupted to remove the spoil.

Advantages of pipe ramming

- The method is relatively less expensive than the previous methods.
- The labor force may be trained to work.
- It is cost effective for shorter and shallower installation.

Disadvantages of pipe ramming

- Only steel castings may be rammed. Concrete castings would be easily damaged.
- It is preferable for shorter ground locations and not hard rock.
- Not cost effective for longer installations.

vi. MOLING

This method is usually used to lay water pipes and heating coils of heat pump systems. Pneumatically driven machines as a mole forces its way through the soil along desired path of the pipe. The standard approach is to dig two holes (one at the origin and the other at the destination) of 1sq. meter and 2m deep.

The mole which is 60cm long and 60mm in diameter is entered horizontally into the earth; pulsed compressed air causes the head of the mole to repeatedly hammer against the soil in front of it. Once the mole has passed, the pipe can be pulled through the horizontal hole. The moles may be steerable.

Advantages of Moling.

- It is very cheap compared to other methods.
- Less skilled labor is required
- Short completion time for short installations
- There is minimal interruption to traffic.
- There is minimal damage to the environment.

Disadvantages of Moling

- Limitations to size of holes that can be made.
- Excavation works are required for pits.
- It is not applicable to a wide variety of ground conditions.

vii. horizontal auger boring

An auger is a device used to move material by means of a rotating helical fighting. The fighting may or may not be encased. Small augers can be mounted on the back of utility truck. Auger drilling is restricted to generally soft on unconsolidated material or weak weathered rock.

Advantages of horizontal auger boring

- It is relatively cheap compared to pipe jacking, micro tunneling and directional boring.
- There is minimal interruption to traffic.

Disadvantages of horizontal auger boring

- It requires skilled labor to operate machinery.
- There is limited variety of ground conditions to which auguring can be applied.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This chapter comprises of the methods and steps that were followed to achieve the specific objectives stated. This involved the following activities;

3.1 Data collection

3.1.1 Primary data.

This includes all the information that was collected specifically for the purpose and the need to design the utility duct from Reconnaissance survey, topographic survey and geotechnical investigations that will be carried out.

3.1.1.1 Reconnaissance survey

This involved moving along the road to study and identify the features within the road, the type of settlement where the road passes, the type of utilities needed and the method of installation to be used.

3.1.1.2 Topographical survey

The length of the road was obtained by using the existing chainage points along Kimera road marked on the existing features running along the road to determine the position of all natural and manmade features within the road.

3.1.1.3 Traffic assessment

This involved Traffic count, which was carried out to obtain the traffic class and use the class, obtained with the subgrade class to obtain the layers of the pavement to know the depth at which to install the duct. This was done using a manual method considering both directions of the lane. The traffic count carried out was recorded in traffic count forms that provided for vehicle counts per day. The traffic count was carried out for 12hours for seven consecutive days both weekdays and weekend from 7am to 6pm

Design information

From RDM- V3 Table2.1

Design life=15 years

Traffic growth rate

From RDM-V3-2.2(iii) r= (2-15%) =5%

3.1.1.4 Subgrade strength assessment

This involved investigating the geological conditions of the soil from the samples of the soil at the selected points along the road to determine the equipment and material needs so as to ascertain whether the soil was compatible with the designed duct by carrying out the soil tests named in the table below.

Table 3.1 Showing soil tests carried out

Test no	Reference method	Name of test
1	BS 1377 part 2,1990	Atterberg limits
2	BS 1377 part 4,1990	CBR test-3point method
3	BS 1377 part 2,1990	Particle size distribution(wet sieving)

(i)Atterberg limits

This was carried out to know if soil had the correct amount of shear strength and not too much change in volume as it expands and shrinks with different moisture contents. This included determining the Plastic limit, liquid limit, linear shrinkage as well as the plasticity index of the subgrade material by computing the average of the moisture contents to determine the plastic limit (PL). Check to see if the difference between the water contents is greater than the acceptable range of the results.

Hence, calculate the plasticity index.

PI=LL-PL

LS = (L_S/L) *100 where L is the length of the mould and L_s is longitudinal.see appendix 4

(ii)Particle size distribution.

This was done to determine the grading coefficient in order to determine whether it was appropriate for the project. Sieve analysis method was used because of its simplicity, cheapness and ease of interpretation. See appendix 3

(iii)California bearing ratio (CBR)

This was performed to help in the evaluation of the mechanical strength of the subgrade. See appendix 2

3.1.1.5 Determining the structural capacity of the duct.

The duct was designed to withstand uniformly distributed high way live load of about $70KNm^{-2}$ obtained from the graph according to BS 5400 considering HA live loading on pavement which represents normal traffic.

The utility duct was designed as open ended thick walled pressure vessels that are subjected to a uniform external pressure resulting from over burden stresses and highway surcharge loading. Thick walled are those with thickness that exceeds 7% of the inner diameter

3.1.1.5.1 Loads applied on concrete utility duct.

The loads applied on the concrete utility ducts are due to overburden stresses from overlying pavement material and surcharge load due to highway loading. A properly designed pavement would transmit negligible live load through the pavement to the underlying concrete duct according to American Concrete Pipe Association as such; the live load may be neglected in the design.

However, a more conservative design will be applied in which alive load is considered. There are two types of Highway live loading according to the BS 5400 Part 2. These are HA and HB loading. HA loading is a formula loading representing normal traffic while HB loading is abnormal vehicle unit loading. According to the Civil Engineering Manual Volume V (EDD, 1983), highway structures that span less than 15m and are situated along roads other than trunk roads or main roads maybe designed for type HA loading only. The figure below illustrates the loading curve for HA uniformly Distributed load, which was used to obtain a highway live load surcharge for use in the design of the concrete duct.

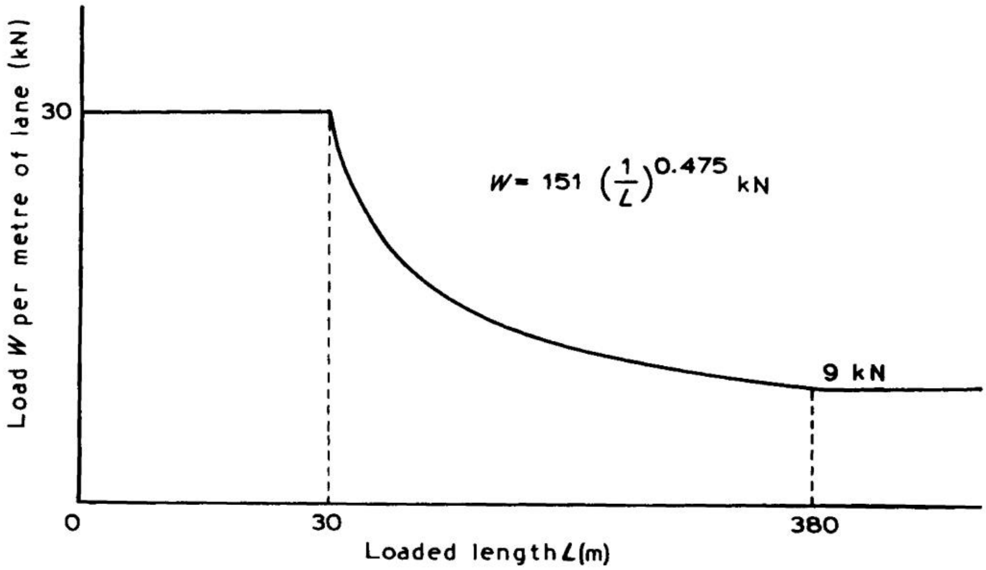

Figure 3:1 showing HA Loading used to design for the duct.

The loaded length of the road considered in the design of concrete utility duct falls within the range of 0 to 30m as seen from the Figure 3:1 above. The duct is usually influenced by load that act with in its immediate vicinity along the road. Therefore, a surcharge of 30KN per meter of lane was used in the design of the duct. The load is assumed to act upon a length of road 3 times the width of the duct (i.e. 7m loaded length). This gives a uniformly distributed high way live load of about 70KNm^{-2}.

3.1.1.5.2 Calculation of stress on duct

The duct was assumed to be installed at a depth of 2m below the pavement surface. The bulk unit weight of sub-base and base course was not obtained in the laboratory. A conservative figure of 20kNm^{-3} was assigned for use in the design

Overburden stress at 2m depth, 6_v;

$6_{v=}$70KNm^{-3}+ (20KNm^{-3}*2m) =110KNm^{-2}

Applying a load factor of 1.5 according to BS 5400

6_v =1.5*110=165KNm^{-2}

Therefore, $6_{v=}p_{o.}$ Given r_1=0.48m and t=0.05m (i.e. r_0 = 0.50), Thus $6_0(max)$ is given by $6_0(max) = (2(p_0 r_0^2)/ (r_0^2-r_1^2))$ =4209KNm^{-2}=4.209Nmm^{-2}

And $6_0(max) \leq f_1 = 0.45f_{cu}$ was used as the governing equation for the structural design according to the Reinforced and prestressed concrete by RH. Evans.
Therefore, minimum characteristic strength of concrete required is given by:
4.209/0.45=9.4Nmm^{-2}
I.e. $f_{cu} \geq$ 9.4Nmm^{-2}

Concrete of grade 15 (i.e. f_{cu} of 15Nmm^{-2}) would be adequate for use in the ducts. Nominal steel reinforcement is provided in consideration of incident loads during transportation and installation as well as being used as a mechanism of controlling crack width. Nominal steel reinforcement for concrete members under compression is specified as 0.4%BH according to Mosley at al, 1999; where b is the width of member and h is its height (i.e. its thickness). Considering a meter width of the member.

A_s=0.4%BH = (0.4/100) (1000*50) =200mm^2

3.1.1.6 Design considerations.

The following considerations were taken during the design for the utility duct

a. The size of the duct, this depended on the type of utilities to be installed through it. The duct was to be of such a size to allow installation of multiple utilities such as water pipes, telecommunication lines etc.

b. Depth at which the duct was to be installed, the depth at which the duct was to be installed based on the need for accessibility and minimum structural capacity requirements for the duct, the maximum depth will be 2m and 1.2m minimum below the existing road pavement.

c. Method of installation to be used, the method of installation depended on the commonly used trenchless technology method and the optimum evaluated basing on the suitability of its application along the project road with minimum damage to the existing pavement.

d. The nature of the loading on the pavement, this was to ensure that the duct to be designed withstands the maximum axle loads expected along the project road.

e. The duration of the works, this was considered to ensure minimum disruption of normal traffic activities and installation cost which depended on the method of installation.

3.1.1.6.1 Choice of installation method

As explained in detail in section 2.3.6.1, there are generally seven methods of trenchless technology namely: Tunneling (T), Micro tunneling (MT), Horizontal directional drilling (HDD), Pipe ramming (PR), Pipe jacking (PJ), Moling (M), Horizontal auger boring (HAB). The seven methods are evaluated for their stability of application to the project road. The method that was evaluated as the most optimum is then used as the basis of the design of an innovative method of installation of utility ducts

3.1.1.6.2 Quantitative evaluation of the methods.

Various criteria were considered in evaluation of the method of trenchless technology, namely cost of works, materials used, size of duct, nature of labor required, duration of works, and applicability to ground conditions along project road, noise levels and effect on local environment, disruption of traffic and construction risks.

A scoring system was used to evaluate the different trenchless technology methods. Scores attached to performance of a method in a particular aspect ranged from 5 to 1, with 5 implying that the method is highly advantageous in a particular aspect while 1 implies that it is highly disadvantageous. Weights of importance were attached to the various criteria considered. The table shows qualitative evaluations of trenchless technology.

Table 3.1: Quantitative evaluation of the methods

Item	T	MT	HDD	PR	PJ	M	HAB
Cost of works	1	1	1	3	3	4	3
Materials and equipment	1	1	4	4	4	4	4
Size of the duct	3	3	5	5	5	1	5
Nature of labor required	1	1	1	3	3	4	3
Duration of works	2	2	4	4	1	4	4
Applicability to existing conditions	1	1	1	5	1	3	5
Effect on local environment	2	2	5	3	3	4	4
Traffic disruption	2	3	3	3	3	3	3
Construction risks	2	2	4	3	2	4	3
Composite score	1.67	1.78	3.11	3.67	2.78	3.44	3.78

According to the scoring system in the Table 3:3, Horizontal Auger boring scores highest followed by pipe Ramming and Moling. The perfect composite score would be 5. Therefore, the Horizontal Auger boring method has a suitability rating of approximately 80%. This implies that significant modifications are required to increase its suitability for use along the project road. The scores were awarded basing on the qualitative evaluation.

3.1.1.6.3 Modifications to the horizontal auger boring method

- Need to minimize workspace required.
- Provide ducts of size 0.5m
- Ensure cost effectiveness for short road crossings (about 9m)
- Employ simply techniques for use by low skilled labor
- Use locally available material
- Minimize risk of road pavement settlement.

(i) Minimizing work space required

To minimize the workspace requirement, small augers that may be mounted onto a truck or fastened to the ground by a special mounting system may be used. The lower the capacity of the auger however, the more man-hours will be required to complete a task. Therefore, a balance should be struck between minimizing man-hours and workspace. The capacity of an auger is measured by auger diameter, pitch flights, lengths, and maximum revolutions per minute. The maximum capacity of the auger is dependent on its motor size. Larger augers usually have large motors. Therefore, smaller augers, though limited in capacity, have the advantage of minimizing workspace requirement.

(ii) Providing ducts of size 0.950m

The need for moderate sized ducts of about 0.950m was the major factor that disqualified Moling as the method of choice despite its other numerous advantages. A mole would require quite a number of multiple passes to provide a nearly as large duct. A small auger would require a much lower number of passes. An auger diameter of 6 to 8 inches would be suitable for this task.

(iii) Ensure cost effectiveness for short road crossing

Horizontal Auger Boring is one of the more cost effective methods for short shallow road crossings. In suitable ground conditions, properly executed auger boring can be a quick and economic technique. To minimize cost of operation, extreme caution will be ensured in critical work tasks such as stabling correct boring alignment and insertion of linings.

(iv) Employ simple techniques for use by low skilled labor

The work procedure should involve use of simple techniques for tasks such as excavation of work pits, establishing of correct boring alignment, insertion of linings etc. The work method should involve use of techniques that can be easily taught to low skilled labor. For instance, the insertion of linings will simply require the men to push the linings through the bored length. Steps will be taken to minimize friction between surface of lining and the ground.

(v) Use locally available materials

The materials for use in the installation of utility ducts should be locally available or easily manufactured by local manufacturers. This consideration will minimize costs of implementation

(vi) Minimize risk of road pavement settlement

The most common risk associated with horizontal auger boring is the possibility of road pavement settlement. Minimization of this risk can be achieved by controlling passage of traffic over the road during the course of operations as well as proper control of boring length before insertion of lining.

3.1.1.6.5 Installation procedures

The installation procedures for utility duct is as follows:

The location at which the utility duct will cross the road is selected. Once selected, work pits of 1.5m by1.5m cross section are excavated either side of the road. The works pits should be along a desired alignment of installation. This desired alignment is established by means of string stretched out across the road. The depths of these excavation are dependent on how high the road surface is above its surroundings at this location. The excavation should allow access to a depth of 1.2m to 1.2m below road surface.

The auger is lowered into the pits, secured firmly to the ground and set at appropriate height required to achieve desired depth of installation. For hand-held augers, advice should be provided within the pit upon which the auger is rested during boring intermissions. The string is stretched out across the road is used to establish the proper alignment of boring. Marks are made in both pits to indicate points of entry at specified depths. Boring begins once points of entry are marked. Special caution must be taken in regard of the angle at which auguring is done. The auger should be maintained perfectly level to ensure a uniform depth of boring.

3.1.1.6.6 Design of the duct.

The duct was designed to be installed at the depth of 2m having a diameter of 0.095m to hold three utility ducts spaced at 0.20mm. Therefore, Y10 bars are provided at 200mm spacing both longitudinally and laterally.

3.1.2 Secondary data

The existing chainage points along Kimera road which includes the following areas of Salima Apartments (CH 0+050), Jesus Christ Church (CH 0+100), Youth Centre (CH 0+300), Kingdom Hall Jehovoh's Witnesses (JW ORG) (CH 0+350) were selected for

Internet was used to guide in obtaining the right location of the road by searching for the Google map.

Design manual like AASHTO 2000 among others

CHAPTER FOUR: RESULTS AND ANALYSIS

4.0 Introduction

This chapter comprises of the results and analysis used to design the underground duct.

4.1 Traffic analysis.

This involved determing the following to get the traffic class;

1. Determination of cumulative Traffic, T

$T=\sum_i T_i$

Where T_i=365 FWGY (10^{-6}) in msa

2. Unidirectional traffic flow, f

   Assuming 1:2 directional traffic split, then

   F=2/3 of the traffic volume for each vehicle class

   For, cars, F_o= 2/3×1320=880 veh/day

   For taxis, Fo= 2/3×2320=1

   547 veh /day

   For buses, F_O =2/3×120=80 veh/day

   Trucks (1 rear axle) F_o= 2/3×180=120 veh/day

   Trucks (2 rear axle) F_O=2/3×48 = 32 veh/day

   Projection Traffic

   Cars, $F_p = F_o\ (1+r)^n$

   $F_P=885(1+0.05)^{15}=2231$

   Taxes, $F_P=1555\ (1+0.05)^{15}=1269$

   Buses, $F_p=81(1+0.05)^{15}=1153$

   Trucks (2 rear axle) =$F_P=120(1+0.05)^{15}=173$

Trucks (3 rear axle) =$F_P=32(1+0.05)^{15}=46$

Wear factor, W

From RDM - V3,

W = $\left[\frac{\text{Axle load in tons}}{8.16}\right]^{4.5}$ in e.s.a

For, cars

$W = \left[\frac{1.00}{8.16}\right]^{4.5} + \left[\frac{2.00}{8.16}\right]^{4.5}$ = 0.0001+0.0018 = 0.0019 e.s.a

For taxis; $W = \left[\frac{1.00}{8.16}\right]^{4.5} + \left[\frac{2.00}{8.16}\right]^{4.5}$ = 0.0019 e.s.a

For buses; $W = \left[\frac{3.00}{8.16}\right]^{4.5} + \left[\frac{6.00}{8.16}\right]^{4.5}$ = 0.0111+0.2507=0.2618 e.s.a

For trucks (1 rear; $W = \left[\frac{4.00}{8.16}\right]^{4.5} + \left[\frac{8.00}{8.16}\right]^{4.5}$ = 0.0404+0.9147 = 0.9551 e.s.a

For trucks (2 rear); $W = \left[\frac{4.00}{8.16}\right]^{4.5} + \left[\frac{8.00}{8.16}\right]^{4.5} + \left[\frac{8.00}{8.16}\right]^{4.5}$ = 0.0404+0.9147 +0.9147 = 1.8698 e.s.a

Growth factor, G

According to Portland

$G = (1 + r)^{0.5n}$

$G = (1+0.05)^{0.5\times15} = 1.44209$

Table 4.1 showing results of Traffic Assement.

vehicleclass	Wear Factor, W			F						
	FrontAxle (esa)	Rear 1 (esa)	Rear 2 (esa)	Fo (veh/d)	Fp	Rate r %	W (esa)	G	Y (yers)	Ti
Passanger cars	0.0001	0.0018	0	880	1269	5	0.0019	1.442	15	0.033
Taxes	0.0001	0.0018	0	1547	2231	5	0.0019	1.442	15	0.019
2-axle Truck	0.0404	0.9144	0	120	173	5	0.951	1.442	15	1.305
3-axle Truck	0.0404	0.9147	0.9147	32	46	5	1.8698	1.442	15	0.679
Buses	0.0111	0.2507	0	80	115	5	0.2618	1.442	15	0.238
Cum Design T										2.274
Design trafficClass										T4

The traffic class obtained was T4 from the table 4:3 below falling in the range of 1.5 to 3.0.

Table 4:2 showing the traffic class.

Traffic Classes	T1	T2	T3	T4	T5	T6	T7	T8
Ranges (msa)	**< 0.3**	0.3 - 0.7	0.7 - 1.5	1.5 - 3.0	3.0 - 6.0	6.0 - 10	10_17	17 – 30

Source: TRL (1993)

This traffic class obtained was used with the subgrade class, which was class S5 to know the pavement layers which was used get the depth of duct at which it was to be installed.

4.2 Subgrade assessment

This consists of the results obtained from all the tests and experiments carried out as summarized below in the table.

Table 4.3 showing results for subgrade

TEST	VALUE OBTAINED	MIN-MAX VALUES(MOWT MANUAL RECOMMENDATIONS)	COMMENT
Lab CBR	28.7%	15-30%	The subgrade was strong according to MoWT road design manuals recommendations
Atterberg limits	19.5%	19%-25%	Values obtained are within the recommended range by MOWT road design manuals 2010
Particle size distribution(grading modulus)	2.6	2-5	According to MoWT, road design manual. The values obtained fall in the grading envelope

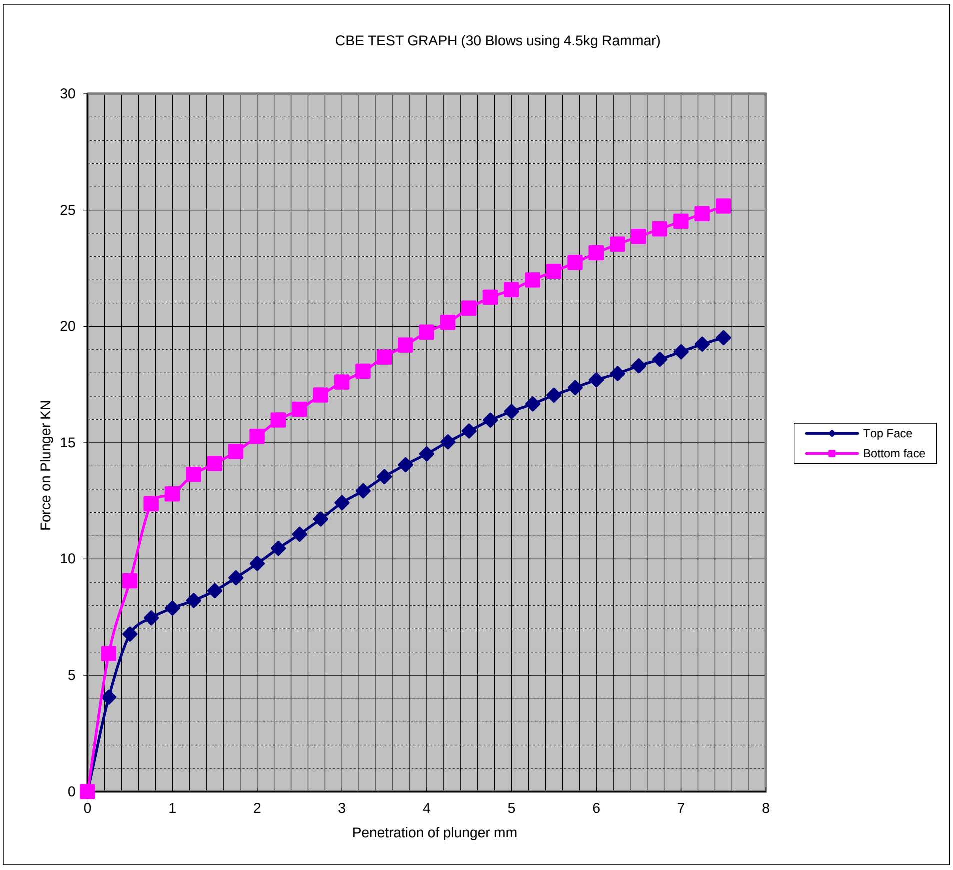

Figure 4.1 Showing CBR Graph plot

The high CBR valve according to the figure 4:1 indicates inducts that the soil is good hence; the subgrade strength can withstand the stresses on the duct.

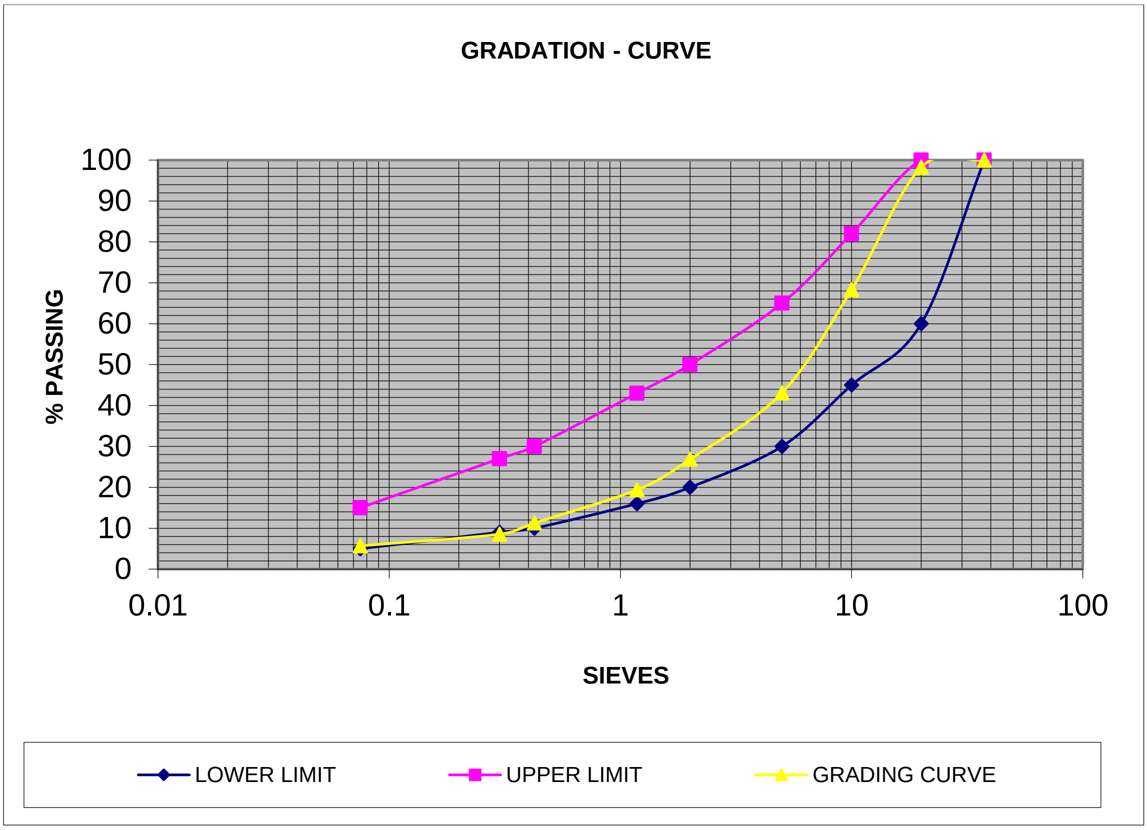

Figure 4.2 Showing the graph for the particle size distribution

From the sieve analysis test, it was discovered that the material was within the grading envelope as seen from the figure 4:2 above.

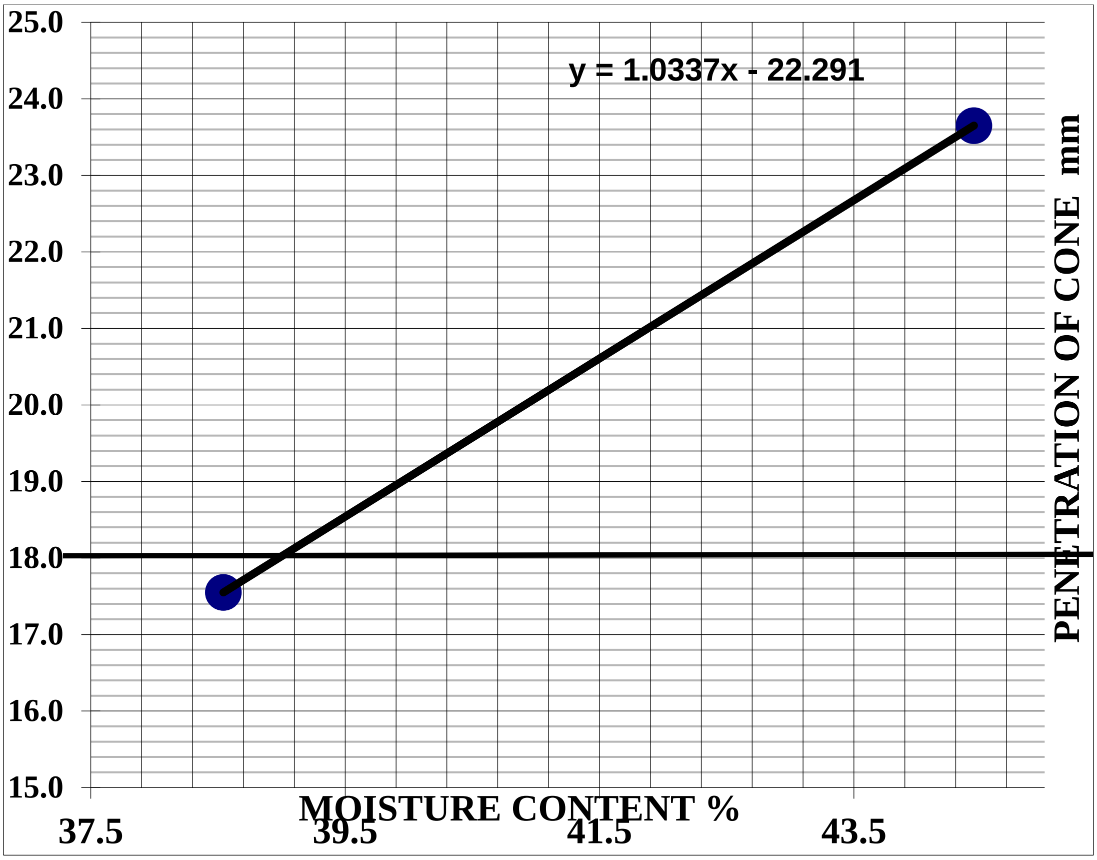

Figure 4.3 Showing the graph for atterberg limits

The plastic index was 19.5% according to the figure 4:6, which was also within the range thus recommended for use.

4.3 The structural capacity of the required duct.

A conservative figure of $20kNm^{-3}$ was assigned for use in the design

Overburden stress at 2m depth, 6_v;

$6_{v=}70KNm^{-3}+ (20KNm^{-3}*2m) =110KNm^{-2}$

Applying a load factor of 1.5 according to BS 5400

$6_v =1.5*110=165KNm^{-2}$

The duct was designed to withstand uniformly distributed high way live load of about $70KNm^{-2}$ obtained from the graph according to BS 5400 considering HA live loading on pavement which represents normal traffic.

4.4 The designed method of installation.

The Horizontal Auger boring method was evaluated as the best method for installation of the duct having the highest score as seen from the table below.

Table 4:4 showing the different composite scores for trenchless methods.

Trenchless methods.	T	MT	HDD	PR	PJ	M	**HAB**
Composite score	1.67	1.78	3.11	3.67	2.78	3.44	3.78

CHAPTER FIVE : CONCLUSION AND RECOMMENDATIONS

5.0 Introduction.

This chapter comprises of the conclusion and recommendations.

5.1 Conclusion

- From the analysis of installation methods, Horizontal Auger Boring was chosen as the suitable method for the condition in Uganda.
- The material tested had 95.7% CBR and therefore it was appropriate to support the duct without shearing.

5.2 Recommendations.

- Utilities should be designed to preserve and protect the structural integrity, aesthetic quality safety, maintenance and the highway during construction.
- The design, location and manner in which utilities are installed should conform to the guidelines.
- Most of the methods used in Trenchless Technology are rather foreign. This calls for appropriate modifications to suit our conditions here in Uganda.
- Underground installations should be of durable Materials designed for long service life expectancy and be relatively free from routine servicing and maintenance.
- All permits for utility works should include provision for the safety and protection of the road users, as well as providing a safe workspace for the utility works.

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APPENDIX I : LAB TEST

DATE : 3/14/2019

Teclab ltd
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WEIGHT = 3820 G

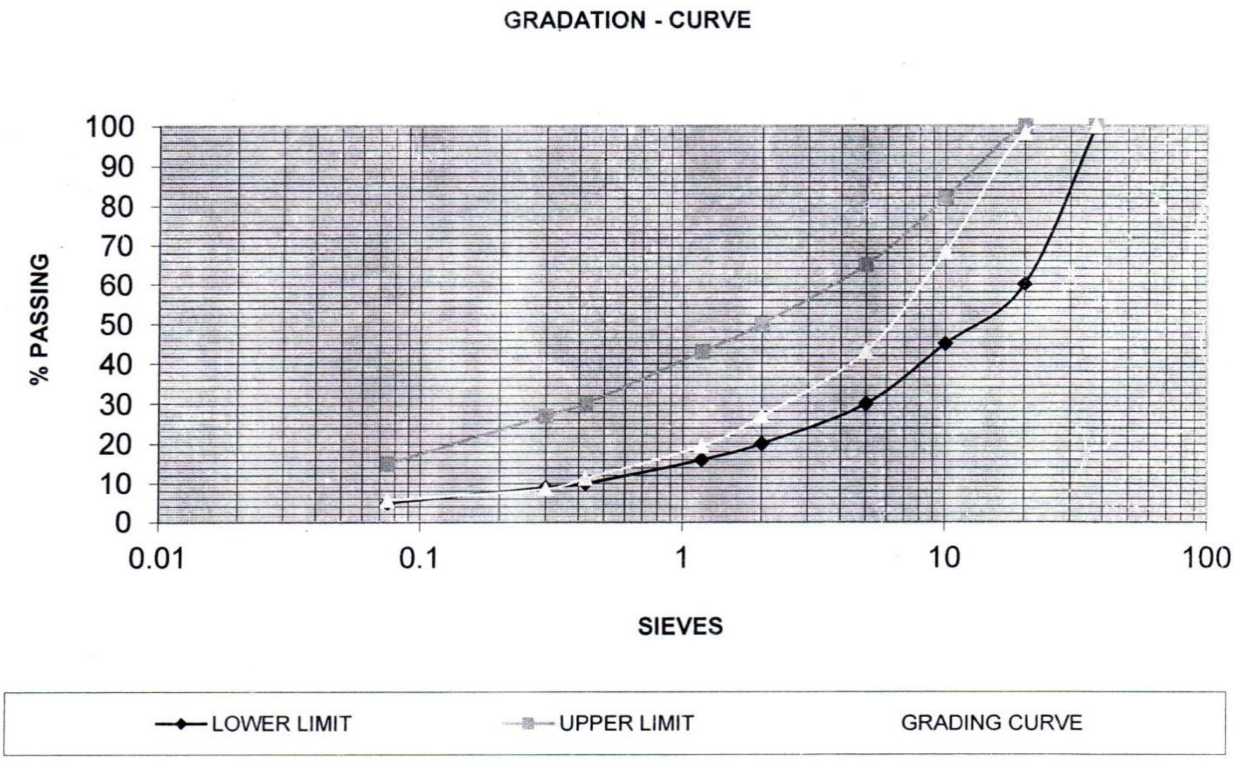
DESIGNING A UTILITY DUCT, KIMERA ROAD

CHAINAGE : COMBINED SECTION MATERIAL

SAMPLE DEPTH :

SAMPLE DESCRIPTION : LATERITIC MATERIAL

BS METRIC SIEVES 1.1	MAXIMUM WT ON SIEVES	WEIGHT RETAINED ON EACH(g)	% RETAINED ON EACH SIEVE	CUMM ULATIVE % RETAINED ON SIEVE	% PASSING	SPECIFICIED	
						LOWER LIMIT	UPPER LIMIT
37.5	3500	NIL	NIL	NIL	100	100	100
20	2000	67	1.75	1.75	98	60	100
10	1000	1143	29.92	31.67	68	45	82
5	600	964	25.24	56.91	43	30	65
2	200	620	16.23	73.14	27	20	50
1.18	100	285	7.46	80.60	19	16	43
0.425	75	310	8.12	88.71	11	10	30
0.300	50	105	2.75	91.46	9	9	27
0.075	25	109	2.85	94.32	6	5	15
PASSING		217	5.68	100.00			
						GRADING MODULUS = 2.6	



Signed.....................
Nanteza Joyce
Laboratory In-charge

TECLAB LIMITED
THE ENGINEERS LABORATORY
P. O. BOX 24934, KAMPALA

CONSULTANT	CLIENT:	CLIENT
	BRIAN AND EVELYNE	K I U STUDENT TEAM

DESIGNING A UTILITY DUCT, KIMERA ROAD

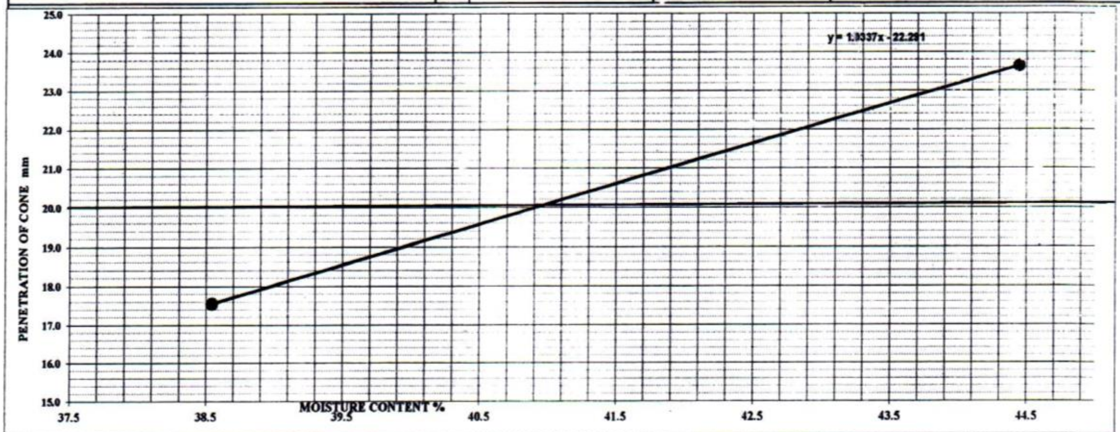
Sample Reference		Sampling date	
Location	COMBINED ROAD MATERIAL 0+350	Testing date	3/17/2019
Depth		Technician	JOYCE

Test Number		1		2	
Container number		A6		A1	
Mass of wet soil + container	g	23.1		24.4	
Mass of dry soil + container	g	22.1		23.2	
Mass of container	g	17.9		17.3	
Mass of moisture	g	0.9		1.2	
Mass of dry soil	g	4.2		5.9	
Moisture content	%	22.6		20.3	
Average moisture content	%	21.4			

LIQUID LIMIT(%)

Test No		1		2		3		4		5	
Initial dail gauge reading	mm	0	0	0	0						
Final dail gauge reading	mm										
Penetration	mm	17.5	17.6	23.6	23.7						
Average penetration	mm	17.6		23.7							

Container number		JK	HN	MV	G						
Mass of wet soil + container	g	81.7	80.8	92.3	93.8						
Mass of dry soil + container	g	65.0	64.0	72.3	73.2						
Mass of container	g	21.3	20.8	27.5	26.6						
Mass of moisture	g	16.7	16.8	20.0	20.6						
Mass of dry soil	g	43.7	43.2	44.7	46.6						
Moisture content	%	38.2	38.9	44.7	44.2						
Average moisture content	%	38.5		44.4							



Liquid limit (%)	40.9
Plastic limit (%)	21.4
Plasticity Index (%)	19.5

Signed ....
Nanteza Joyce
For chief materials' engineer

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C.B.R. TEST / PENETRATION

Project:	DESIGNING A UTILITY DUCT, KIMERA ROAD
Location/Source/Depth:	**CH : KM 0+014**
Material Description:	

Sample Reference							Sampling Date	
Technician							Testing Date	
Number of blows per layer		65 (4.5 Kg Rammer)				30 (4.5 Kg Rammer)		
Number of layer		5				5		
Mould No.		Q				Q		
			F1	0.022125	KN		F2	0.022125
Speed : 1 mm/min.		Top		Bottom		Top		Bot
Penetration of the plunger (mm)		Gauge Reading (Div)	Force (KN)	Gauge Reading (Div)	Force (KN)	Gauge Reading (Div)	Force (KN)	Gauge Reading (Div)
0.00		0	0.00	0.0	0.00	0	0.00	0
			0.00	0.00	0.00	0.00	0.00	0.00
0.50		40	55.00	90	1.99	30	0.66	60
			0.00	0.00	0.00	0.00	0.00	0.00
1.00		70	1.55	160	3.54	60	1.33	90
			0.00		0.00		0.00	
1.50		107	2.37	230	5.09	75	1.66	170
			0.00		0.00		0.00	
2.00		140	3.10	280	6.20	94	2.08	151
2.50		174	3.85	280	6.20	110	2.43	230
			0.00		0.00		0.00	
3.00		205	4.54	320	7.08	140	3.10	260
			0.00		0.00		0.00	
3.50		230	5.09	420	9.29	160	3.54	290
			0.00		0.00		0.00	
4.00		255	5.64	470	10.40	175	3.87	350
			0.00		0.00		0.00	
4.50		280	6.20	530	11.73	190	4.20	380
			0.00		0.00		0.00	
5.00		300	6.64	600	13.28	240	5.31	400
			0.00		0.00		0.00	
5.50		320	7.08	645	14.27	350	7.74	420
			0.00		0.00		0.00	
6.00		348	7.70	690	15.27	375	8.30	460
			0.00		0.00		0.00	
6.50		400	8.85	720	15.93	410	9.07	490
			0.00		0.00		0.00	
7.00		430	9.51	760	16.82	420	9.29	530

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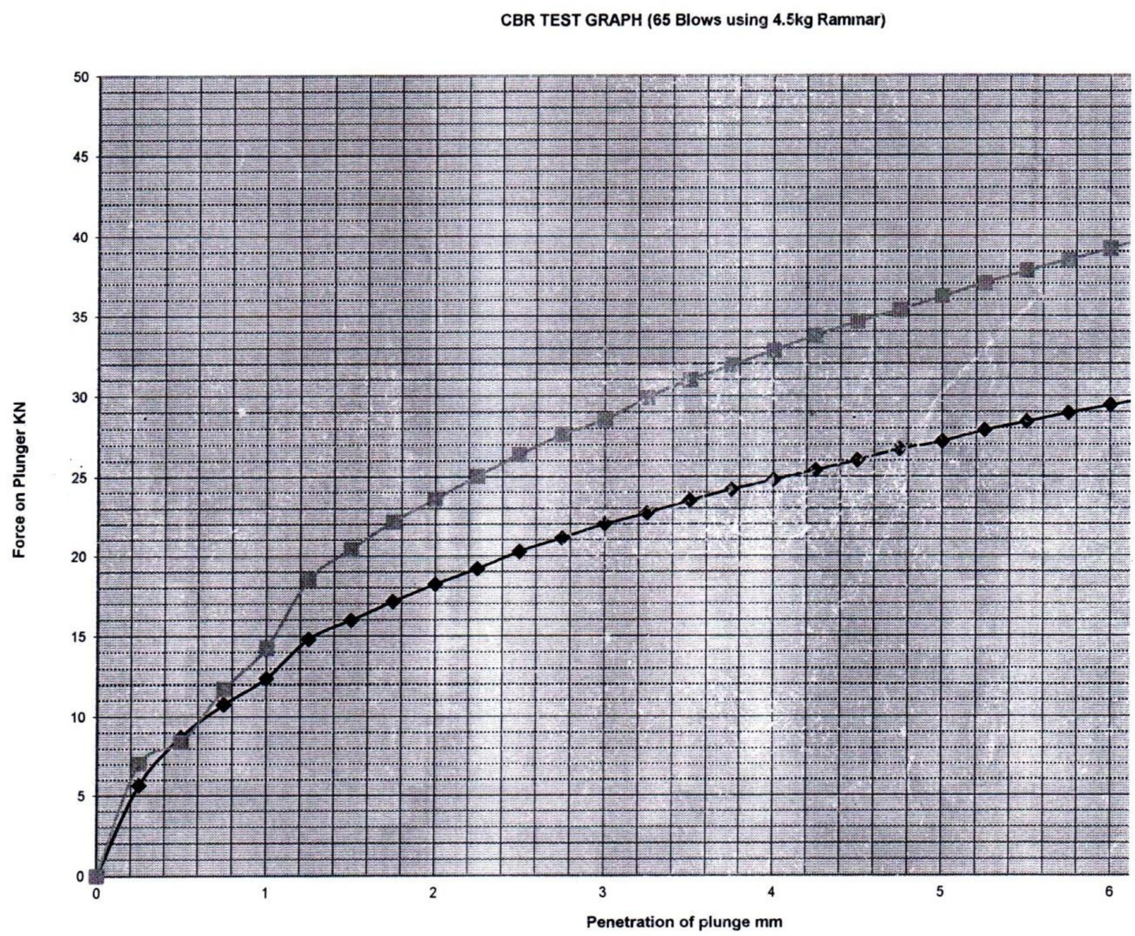
C.B.R. TEST GRAPH (65 Blows Using 4.5 Kg Rammer)

Project:	DEIGNING A UTILITY DUCT, KIMERA ROAD	
Location/Source/Depth:	**CH : KM 0+600 - 1+100**	
Material Type:		
Sample Reference		Sampling Date
Technician		Testing Date



					0.00		0.00	
7.50		465	10.29	800	17.70	450	9.96	580
Proving Ring capacity			50KN					

CONTRACTOR				
KIU STUDENTS				
14-Mar-2019		Test Condition		
21-Mar-2019		4 Days Soaked		
	10 (4.5 Kg Rammer)			
	5			
	Q			
KN			0.022125	KN
tom	Top		Bottom	
Force (KN)	Gauge Reading (Div)	Force (KN)	Gauge Reading (Div)	Force (KN)
0.00	0	0.00	0	0.00
0.00	0.00	0.00	0.00	0.00
1.33	24	0.53	45	1.00
0.00	0.00	0.00	0.00	0.00
1.99	29	0.64	60	1.33
0.00	0	0.00		0.00
3.76	35	0.77	75	1.66
0.00		0.00		0.00
3.34	17	0.38	84	1.86
				0.00
5.09	43	0.95	92	2.04
0.00		0.00		0.00
5.75	57	1.26	105	2.32
0.00		0.00		0.00
6.42	62	1.37	112	2.48
0.00		0.00		0.00
7.74	84	1.86	120	2.66
0.00		0.00		0.00
8.41	105	2.32	135	2.99
0.00		0.00		0.00
8.85	112	2.48	145	3.21
0.00		0.00		0.00
9.29	130	2.88	170	3.76
0.00		0.00		0.00
10.18	145	3.21	190	4.20
0.00		0.00		0.00
10.84	165	3.65	235	5.20
0.00		0.00		0.00
11.73	180	3.98	280	6.20

0.00		0.00		0.00
12.83	220	4.87	320	7.08
50KN			50KN	

			Top Face	Bottom Face	Average			
CBR % at a Penetration of		2.5 mm	29.16	46.93	38.05			
		5.0 mm	33.19	66.38	49.78			

APPENDIX II: DRAWING