International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 4 Issue 9, September – 2020, Pages: 9-17

Geotechnical Assessment of Subgrade And Sub-Base Quality for The Design And Construction of Road Pavement In Parts of the Coastal Section of Kasese District, Western Region, Uganda.

LION ENGR. ITAFE VICTOR ADACHA, HND (Civil), PGDPM, MNATE, MNSE, COREN

Directorate of Technical Aid Corps, Ministry of Foreign Affairs, Abuja, Nigeria
Kampala International University, Faculty of Engineering Department of Civil Engineering
Western Campus, Ishaka, Uganda
Email: viadacha2006@gmail.com

Abstract: *Pre-design and construction geotechnical assessment of subgrade and sub-base materials was carried out for optimal performance and pavement sustainability. Method involved boring of 59holes and trial pits, sampling and geotechnical testing. Soil profile indicates a top inorganic clay layer (CL) from surface to an average depth of 0.55m, a silty sand layer (ML and MH) to 1.1m and a poorly graded sand layer (SP) to 2.0m. Subgrades classify as USCS CL – CI clays, AASHTO A3, A-2-4, A-2-6, A-2-7, A-7-6, A-7-5 with 58.85% of the subgrades rated as poor to fair and 41.15% good to excellent. Subgrades clay activity varies from 0.8 to 41.25 and expansivity from 4.83 to 68.90 indicating presence of extra - sensitivity and quick and expansive clays, 48hours soaked CBR from 7% to 38% and surface modulus (Es) from 61.5 MPa to 168.14 MPa. Subbase fills have moisture content, liquid limit, plastic limit and plasticity index of 15 – 20%, 24 – 34%, 13 – 22% and 9 – 15 respectively, composed of 29.8% fines (clay and silt classes) and 70.2% sands; AASHTO classified as A-2-6 and rated excellent to good; 48hours soaked CBR of 17.0 – 39.0% and un-soaked CBR of 30 – 58 depicting a 10.0% – 62.0% reduction in strength. The resilient modulus vary from 206.84 – 537.78 (MN/m2), grading modulus from 0.67 – 1.04, and plasticity modulus from 603.0(MPa) – 1395.0(MPa). Pavement thickness has been recommended to be 300 – 350mm based on CBR and group index and coarse granular subbbases of sand and gravely materials for egress of moisture to improve road bed effective stress.*

Keywords—subgrades, sub-bases, kasese distrist, uganda, coastal section, geotechnical properties, road pavement, western region, design quality and construction

1. INTRODUCTION

Road pavements are a key means of transportation forming the fabric of modern day urbanization. It represent significant infrastructure that is critical to the development and economic growth rate of any geographic location Li, McNeil (2011) Reference **[1]** and O'Flaherty (1997) Reference **[2]** Road pavements whether rigid or flexible, are built on the in situ subgrades which provide good support, limit pavement deflections to acceptable standards, minimize differential movement due to frost and shrinkage and or swelling soils, and promote uniformity of support for good long term performance Kadyali and Lal (2008) Reference **[3]**. Soils are also used as sub-base layer fill materials and these heterogeneous and often anisotropic aggregates of mineral grains vary markedly in composition and gradation making the predictability of their engineering behaviour and performance in response to imposed loads under natural consistency in time and space impossible. The stability of any structure depend on the material composition and for roads, subgrade strength, degree of saturation and expected behaviour under saturated conditions control the stability, performance and longevity of the pavement infrastructure. UHDM (2013) Reference **[4]** has recognized the dependence of subgrade strength on the geology of the site which imparts on the pavement among other factors such as traffic stress, earthwork adequacy, protection from floods and wave erosion, surface and subsurface drainage systems, cross drainage etc.

The geotechnical properties of in situ soils directly affect not only the pavement structure design but dictate the type of pavement most suited to a location.

AJEST (2011) Reference **[5]** and UHDM (2009) Reference **[6]** noted that the suitability of a soil for road design requires adequate knowledge of its properties and the factors affecting their behavior and response of the soils.

A subgrades response load is controlled by its composition and environmental factors such as rainfall and temperatures which are climatic factors because these control the amount of moisture, shear strength, pore water pressure and effective stress.

Subgrade strength and traffic load have been reported by DGRPF (2009) Reference **[7]** to be the most important factors in the structural design of pavements whether rigid or flexible. Subgrade provide foundation for the pavement and serves the main purpose of the distributing the applied vehicle loads without causing distress in the foundation layers or in the overlying layers during construction where the stresses will be applied by delivery vehicles, pavers and other construction plant.

The strength and material thickness of the foundation subgrade and subbase layers must be sufficiently high enough to withstand load without damage. A designer cannot change the subgrade and is constrained to design to in situ soil conditions but choice of the subbase fill materials must be such that it possesses sufficient strength to sustain traffic loads and be of uniform and constant quality to spread and compact easily.

Subgrades layers also have to be either protected from, or to be of sufficient durability to withstand environmental effects from rain, frost, high temperature etc. without sustaining damage which may be caused by rutting or other uneven deformation, cracking in hydraulically bound mixtures or other forms of material specific degradation. Pavement foundations must possess sufficient stiffness to carry the stress from the overlying pavement layers to be placed and adequately compacted. It must be capable of absorbing large numbers of repeated loads from traffic during its service life; and deterioration due to water ingress especially if the upper pavement layers begin to crack. It is also essential that excessive deformation does not accumulate within the foundation under repeated traffic loading, since this is a potential source of wheel path rutting at the pavement surface Musisi (2018) Reference **[8]**.

Pavement's performance is thus fundamentally linked with its constituent material layers among other factors such as construction methods, environment, maintenance and rehabilitation.

The design of road pavement seeks to address the problem of construction cost, road quality and cost of maintenance. In addressing the aforesaid, traffic loading, subgrade strength, character of construction materials, drainage, performance and safety reliability are the key factors. Consequently, the designer of a road pavement infrastructure has no choice of the subgrade and has to choose his design based on the in-situ subgrade characteristics. This stresses the importance of adequate geotechnical investigation and correct interpretation of results for design applications MoWTC (1992) Reference **[9]** and sadly this has been neglected in Nigeria and most designs are based on predictions and insufficient information leading to partial or total difference between the design and site specific conditions. This necessitates quality assessment of subgrade soils as a pre-design and construction requirement to determine inter alia, the design criteria, life, and minimum acceptable serviceability level of the infrastructure. It helps to guide the method of construction, selection of suitable materials for use as sub-base and base courses as well as the thickness of the bituminous layer. A detailed geotechnical investigation and correctly interpreted results determine design strength of the subgrade under soaked conditions, specifies compaction density at the optimum moisture content, effective modulus of subgrade, elastic and resilient moduli, drainage conditions and stabilization requirements. It also identifies the most suitable material for use as subbase layer suitable for the specific in situ road bed foundation. All of these parameters are factored into the design Kadyali and Lal (2008) **[3]**. Investigations have shown that most premature road failures in Nigeria especially in the coastal Niger Delta are attributed to weak subgrades, its susceptibility to perennial flooding and pavement deterioration due to excessive surface and groundwater, subgrade compression, settlement, wet land swamps, marshes and bogs of low bearing capacity, poor drainage characteristics Robert et al (2013) Reference **[10]**.

Several researchers amongst who are NCTTCA (2018) Reference **[11]**; MoWTC (1992) Reference **[12]**; UMWT (2015) Reference **[13]**; MoWTC (2017) Reference **[14]**; MoWTC (1992) Reference **[15]** have reported on the weak bearing soils that form the foundation materials of the Western region. The use of lateritic materials as subbase fills has been the common construction practice but Kiggundu (2015) Reference **[16]** has reported that the so called laterites which become soft when wet and significantly hard when air-dried could not be called laterite soils because of the high silica-sesquioxide ratios. UNRA (2016) Reference **[17]** also observed that there is a paucity of data on surficial Kasese district soils relative to the deeper subsurface due to exploration and production activities of International Oil Companies.

The area of study is on the Eastern flank of the AICPI (2013) Reference **[18]** Kasese district with an estimated traffic volume >1000 vehicles per day rated as high and corresponding to >500,000 equivalent standard axial loads owing to the exploration and production activities of major International Oil Companies, service companies and high population density. This traffic volume has impacted heavily on the road infrastructure resulting to frequent failures. This geotechnical characterization of the materials underlying the area was a commissioned study to ensure quality in design and construction for optimal stability and performance of the pavement infrastructure.

2. STUDY LOCATION

Kasese District

Kasese District is located in the Western region of Uganda at 00°11′N 30°05′E, and bordered by the Districts of Kabarole to the Northeast and east, Bundibugyo to the Northwest, Kamwenge to the Southeast, Bushenyi to the South and the Democratic Republic of Congo to the West AICPI (2013) **[18]**. Twelve endemic hazards threaten the District: floods, landslides, drought, animal attacks on crops, animals and human beings, crop pests and diseases, animal pests and diseases, environmental degradation, internal conflict, invasive weed species, hail storms, wild fires and earthquakes.

Flooding is the most serious threat overall, with incidence in Nyakiyumbu, Kisinga, Kyarumba, Kilembe, Maliba, Bugoye, Kaseses Municipal Council, Hima Town Council, Karusandara, Kitswamba, and Mubuku town. Landslide risk ranks second with incidence in Kisinga, Mahango, Kilembe, Bwesumbu, Bugoye, Maliba, Kyabarungira, Buhuhira, and Muhokya. The District has a fairly high level of cumulative vulnerability to hazards. Karusandara is the most vulnerable Sub-county with a weighted vulnerability of 9. Hima Town Council, Katwekabatooro Town Council, Kilembe, Kitswamba, L. Katwe, Maliba, Muhokya, Nyakatonzi, Nyakiyumbu and Nyamwamba Sub-counties are moderately vulnerable with weighted vulnerability values lying between 5 and 7. Kasese District Hazard, Risk and Vulnerability Profile. The rest of the sub counties are less vulnerable to the resident hazards with weighted vulnerabilities well below 5 but should be fortified against occurrences of new hazards and exacerbation of resident hazards now occurring at lower magnitudes but which may be worsened by climate extremes expected in the near future. Timely early warning systems and other DRR interventions would be able to enhance the resilience of the people of Kasese to the effects of climate change.

The Kasese district area is located on the Uganda high plains immediately west of the Rocky Mountains at an elevation of 4,500 feet (1,450 m) Hopers (1965) Reference **[19]**. Because it receives 15-inches (380 mm) of precipitation annually, it is considered to have a semiarid climate. Rainstorms in the spring and early fall often have an "upslope" character where easterly flow of moisture settles against the mountains. These types of rainstorms can have a duration that exceeds 6-hours and, although they may drop relatively large amounts of total precipitation, they are not very intense and are not normally associated with major urban flooding problems along major drainageways. In late spring and throughout the summer, the rainstorms often result from convective or frontal stimulated convective action. These type of storms are often less than 1- or 2-hours in duration; however, they can produce brief periods of high rainfall intensities.

Experience and rainfall/runoff data in the Kasese area show that very little, if any, runoff occurs from low intensity storms such as "upslope" type storms and from the lesser convective storms when the land is not urbanized. As the land develops, streets, curbs and gutters, and storm drainage facilities are installed and runoff occurs from even very small rainstorms.

The terrain in the Kasese area is rolling with moderate to steep slopes. Much of the area has high clay content with tight surface soils; however, there are also areas that have very free draining sandy soils. The native vegetation consists of dry land range grasses, which in some cases were replaced in the past by dry wheat or irrigated crops and are now being replaced by Kaseses Municipal Council the area urbanizes. Since most of the land in new developments has residential land use, the detention study concentrated on an ultimate land use mix consisting of mostly residential with some light commercial.

A study conducted by the District Kaplan (1994) Reference **[20]** used an actual Kasese area watershed as a study basin. The study watershed had an area of 7.85 square miles, a watershed length of 6.4 miles with an average watershed slope of 0.015. Its shape and drainage pattern is shown on Figure 1 and it was estimated that 1.9 percent of its area was impervious before land development began. After full development, the watershed area is projected to be 38 percent impervious.

Runoff was modeled using 2-hour design storms for the 2-, 10-, and 100-year recurrence frequencies. These design storms were developed for the Kasese area using the rainfall-runoff data collected by UGGS since 1970 and the long term Kasese Raingage record collected since 1896. Modeling was done using stationary storms and storms that moved across the watershed at six miles per hour upstream and downstream. In addition, runoff was modeled using three recorded rainstorms under the stationary and moving storm scenarios. Although the runoff results reported in this paper are for the stationary design storm scenarios, the effects of stormwater detention on each storm scenario were found to be similar. Namely, if a reduction in peak flow was calculated with detention for the stationary storm scenario, then a similar reduction was also observed for the moving storm scenario when compared against the undertrained moving storm condition.

Because the modeling was for a 7.85 square mile watershed, conclusions of this study should not be extrapolated much beyond 10 square mile watersheds. This seems like a severe limitation; however, many of the observed rainstorms in the semi-arid climates have a rather limited footprint where the intense rainfall occurs. Thus, controlling runoff from a 10 square mile or lesser watersheds may be very beneficial for flood control purposes in semi-arid climates.

The study of Short and Stauble (1965) Reference **[21]** watershed was subdivided into 56 sub-catchments and 52 channel segments. After calibration, runoff was modeled using the various storm scenarios for the undeveloped and the urbanized land use conditions. The model was then modified to include 28 randomly located detention ponds. The ponds intercepted 91 percent of the total area with runoff from 9 percent of the area being undertrained. Each pond was sized on the basis of the hydrographs calculated for the pre and post-developed conditions. The control volume was estimated using a process illustrated in Figure 2, where the control volume was assumed to be equal to the cross-hatched portion of the runoff hydrograph.

The hydraulic characteristics UMoWT (1997) Reference **[22]** of each pond's outlet were designed assuming that the outlet functioned as an orifice until the design control volume was filled. At that point the ponds were assumed to overflow and a broad-crested weir controlled the overflow. On the basis of trends observed in several individual designs, the outlet discharge versus storage volume relationship was reduced to a non-dimensional form for all ponds. This expedited the design of a large number of ponds under a variety of desired control conditions.

3.0 METHODS OF STUDY

3.1 Field and Laboratory Methods

Field sampling was achieved through the boring of 63 holes using hand auger and trial pits. Soil samples were taken at 1.0m, 1.2, 1.5 and 2.0m depths based on change in soil profile and the specification of 2.0 – 3.0m depth for roads

International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 4 Issue 9, September – 2020, Pages: 9-17

BSI (1990) Reference **[23]**. All samples were roughly examined, described and prepared for laboratory analysis. Geotechnical laboratory tests carried out were in accordance with standard geotechnical engineering practice and the Skempton (1953) Reference **[24]** specifications. Soil's index properties tests include particle size distribution, Atterberg limits, moisture content, density, and specific gravity. Moisture - density relationship was tested by the standard proctor compaction method, while the soaked California Bearing Ratio was determined for subgrade and for subbase materials. Sample soaking aimed at simulating field conditions during the wet periods, was carried out for 48hours in accordance with BS 1377 (1990). Subgrade samples for Particle size distribution test were first washed in ASTM sieve number 200 before being mechanically sieved. All materials passing sieve number 200 were subjected to hydrometer test to determine the clay fractions as most problems caused by road failures are due to clay. Soil compaction test was done using the East African Standard (EASC) proctor test to predict the moisture density behaviour.

3.2 Methods of Data Analysis

3.2.1 Evaluation of Subgrade Quality

Subgrade quality assessment was evaluated based on the Group Index (G.I.) (eqn. 1), California bearing ratio (CBR), elastic modulus (eqn. 2), subgrade surface modulus (eqn. 3) Kadyali and Lal (2008) **[3],** and resilient modulus (eqn. 4) and specific gravity. The compaction behavior of both subgrade and sub-base materials were also evaluated using the AASHTO EASC compaction and moisture density relationships.

$$G.I. = (F200 - 35)[0.2 + 0.05(LL-50)] + 0.01(F200 - 15)(Ip - 10) \quad (1)$$

Subgrade surface modulus

$$Es = 17.6(CBR)0.64 \quad (2)$$

Elastic modulus (E)

$$E = 10(CBR) \text{ in MPa} \quad (3)$$

Resilient modulus (MR) = 10.342(CBR) in MN/m^2 ……………………… (4)

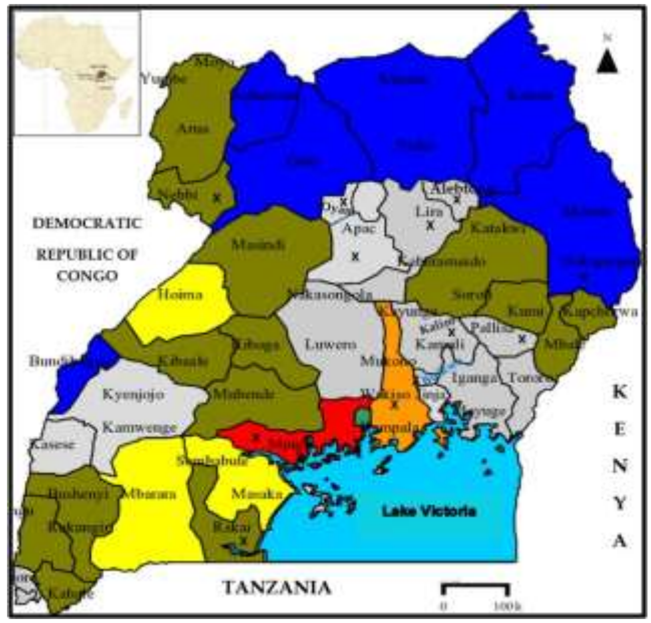


Fig. 1: Map of Uganda showing study area and the climatological districts

3.2.2 Clay Activity and Expansivity

The activity and or expansivity of clayey soils largely influence their volume change behavior. Active and expansive soils are found extensively in tropical areas and their presence greatly affects construction activities and the performance of the structure during its service life. Expansive soils are characterized by the presence of large amounts of high activity montmorillinitic clay minerals which are causes of pronounced volume changes. Sridhara and Prakash (2000) Reference **[25]** noted that the activity of a soil depend on its clay content and the plasticity index and expansivity have been reported to be control by plasticity and amount of medium sand composition in the soil Charles (2001) Reference [**26**] thus determination of these properties of soils is fundamental in because of the preponderance of such soils in the tropics and the high rainfall is very essential.

Many criteria are available to identify and characterize active and expansive soils most of which are based on the soils consistency characteristics such as liquid limit, plasticity index, shrinkage limit, and shrinkage index. In this studies, subgrade activity and expansivity were determined using equation (5) Sridhara and Prakash (2000) **[25]** and equation (6) Charles (2001) **[26]**.

$$A = \frac{\text{plasticity Index}}{\%\ \text{clay}} \quad (5)$$

$$PI_w = \frac{Ip \times F0.425}{100} \quad (6)$$

Where

F0.425 = % medium sand, Ip = plasticity index,

3.2.3 Evaluation of Subbase Quality

The road base layers form backbone of the road pavement and its performance dictates the performance and longevity of the roadway. Generally, the subbase and base course are required to have sufficient strength to sustain the imposed traffic stresses without failure, uniform and consistent quality so that they can be spread and compacted without difficulty and to provide a road surface that will not be impaired by the compacting effort of traffic. Recommended materials for bases and subbases include pitrun gravels, volcanic gravels such as tiff and tarish, marl, trap rock, quarry spoils, crushed slag and crushed rock UMoWT (2000) Reference [**27**].

Subbase course materials' quality was assessed using particle-size grading, plasticity of the fine aggregate, elastic, resilient, grading and plasticity moduli; and the strength based on California bearing ratio (CBR)**.** Particle size distribution and plasticity index provides the basis for determination of the grading and plasticity moduli (eqns. 5 and 6 respectively) UMoWT (2000) **[27]** while the moduli parameters were derived from the soaked CBR (%).

$$Mg = \frac{300 - (F2 + F0.425 + F0.075)}{100} \quad \ldots\ldots\ldots (7)$$

$$Mp = Ip \times F0.424 \quad \ldots\ldots\ldots\ldots (8)$$

Where

F2 = % passing sieve number 2mm

F0.425 = % passing sieve number 0.425mm

F0.075 = % passing sieve number 0.075mm

Ip = plasticity index

4.0 RESULTS AND DISCUSSION

4.1 Soil Profile and Geotechnical Characterization

A typical soil profile characterizing the site's subsurface stratigraphy for the top 2.0m depicts a soft black humus top soil varying in depth from ground surface to approximately 0.8m, a firm light brown silty clay from 0.8 – 2.0m GFC (2016) Reference **[28]**. These subgrade materials classify as low to intermediate plasticity clays (CL - CI) under the unified soils classification scheme, A3, A-2-4, A-2-6, A-2-7, A-7-6, A-7-5 AASHTO materials (figure 2a), with 58.85% of the subgrade materials rated as poor to fair and 41.15% rated as good to excellent. On the basis of the specific gravity (ASTEM D854-92), subgrade materials classify as high porosity organic to inorganic soils in different locations across the study area. These materials have a % clay content ranging from 0.4% t0 8.0%, silt % from 1.6 to 13.5%, together taken as % fines with a range of 3.5% to 19.5% while the remaining soils particles falls within the sand class and a 7.32% gravelly materials (figure 3). The clay activity of the subgrades ranges from 0.8 to 41.25 with a mean value of 11.79 depicting normal to active clays ranging in sensitivity from low to extra-sensitivity and even quick clays in places. Subgrade's expansivity varies from 4.83 to 68.90 with an average value of 19.45. This range of expansivity indicates that most of the soils are expansive (expansivity > 20) Charles (2001) **[26]**.

A typical soil profile characterizing the site's subsurface stratigraphy for the top 2.0m depicts a soft black humus top soil varying in depth from ground surface to approximately 0.8m, a firm light brown silty clay from 0.8 – 2.0m. These subgrade materials classify as low to intermediate plasticity clays (CL - CI) under the unified soils classification scheme, A3, A-2-4, A-2-6, A-2-7, A-7-6, A-7-5 AASHTO materials (figure 2a), with 58.85% of the subgrade materials rated as poor to fair and 41.15% rated as good to excellent GFC (2016) **[28].** On the basis of the specific gravity (ASTEM D854-92), subgrade materials classify as high porosity organic to inorganic soils in different locations across the study area. These materials have a % clay content ranging from 0.4% t0 8.0%, silt % from 1.6 to 13.5%, together taken as % fines with a range of 3.5% to 19.5% while the remaining soils particles falls within the sand class and a 7.32% gravelly materials (figure 3). The clay activity of the subgrade ranges from 0.8 to 41.25 with a mean value of 11.79 depicting normal to active clays ranging in sensitivity from low to extra-sensitivity and even quick clays in places. Subgrade's expansivity varies from 4.83 to 68.90 with an average value of 19.45. This range of expansivity indicates that most of the soils are expansive (expansivity > 20) Charles (2001) **[26]**.

Geotechnical index properties show that the specific gravity varies from 2.44 to 2.60 with an average of 2.53 while the moisture content of the subgrade materials varies from 11.78 – 35.30% with an average of 29.75.

Steele (1945) Reference **[29]** has that specified a moisture content range of 5 – 15% for engineering construction in the country and in this coastal microclimatic terrain with high porosity organic soils, pavement sustainability is suspect. The bulk density varies from 1.541(g/cm^3) to 2.61(g/cm^3) with an average of 2.61 (g/cm^3) while the dry density ranges from 1.253(g/cm^3) to 1.665 (g/cm^3) with averaging 1.40 (g/cm^3). The bulk unit weight varies from 15.12 (KN/m^2) to 25.5 (KN/m^2) averaging 16.87 (KN/m^2) while the dry unit weight ranges from 12.292 (KN/m^2) to 16.334 (KN/m^2) with a mean of 13.734 (KN/m^2).

The consistency and rheological properties of the subgrade depict that 30.51% of the subgrade are non-plastic with a liquid limit range of 25.70% to 54.1% with a mean of 27.32%, plastic limit varying from 8% to 37% and averaging 16.05% and index of plasticity of 5 – 28.4 range and a mean of 14.79.

Subgrade strength properties shows the 48hours soaked California bearing ratio (CBR) to vary from 7% to 38% with a mean value of 9.9% indicating most subgrade to fall into the medium hard ground class UMoWT (2000) **[27]** while its derived moduli depicts the subgrade surface modulus (Es) to range from 61.5 MPa to 168.14 MPa with a man value of 68.82Mpa across the study area and classifying as classes 2 and 3 of pavement foundation classes (table 3) Steele (1945) **[29]**. The modulus of resilience (MR) also range from 72.394(MN/m^2) to 392.996(MN/m^2) with an average value of 114.88(MN/m^2) while the elastic modulus range from

70(MN/m^2) to 380(MN/m^2) with a mean of 105.2(MN/m^2). These soils indicate materials of average to good quality subgrade.

Moisture –density relationships indicates that the Optimum moisture content (OMC) of the subgrade materials varies from 10.5% to 19.40% with an average of 16.06% while the maximum dry density (MDD) range from 16.75 (KN/m^3) to 19.55(KN/m^3) averaging 18.18(KN/m^3) (figure 4). Most of the weak strength materials occurring in some parts of the area are those described by Fidelis (2019) Reference **[30]** as transition zone soils.

The Robert et al (2013) **[10]** has specified that for effective/efficient design of durable pavement, the % passing BS sieve number 200 should not exceed 35%,liquid limit should be less than or equal to 50%, while plasticity index should not exceed 30%. The subgrade materials' simulation of field conditions during wet seasons especially for coastal parts of the country should be soaked for 96 hours and a minimum subgrade soaked California Bearing Ratio of 15% should be design of road pavement without modification. All subgrade which have 96 hours soaked CBR less than 15% must receive treatment to improve its strength and durability.

Subbase

The engineering characteristics of the subbase materials indicates the moisture content, liquid limit, plastic limit and plasticity index to range from 15 – 20%, 24 – 34%, 13 – 22% and 9 – 15 respectively with mean values of 17.0%, 28.9%, 16.8% and 12.1 respectively. Particle size distribution depicts the subbase fill materials to be characteristically composed of 29.8% fines (clay and silt classes) and 70.2% sands. These materials classify as A-2-6 AASHTO materials rated as Excellent to Good (figure 2). A 48hours soaked CBR range of 17.0 – 39.0% with an average 28.2% and un-soaked CBR range of 30 – 58 with a mean value of 45.7% characterize the subbase fill materials with a percent reduction in strength of 10.0 – 62.0%.

The elastic modulus range from 170(MN/m^3)–350(MN/m^3) with a mean value of 273 (MN/m^3), resilient modulus varies from 206.84 – 537.78 (MPa) with an average value of 353.696 (MPA). The grading modulus ranges from 0.67 – 1.04 with an average of 0.849 while the plasticity modulus varies from 603.0(MPa) – 1395.0(MPa) averaging 906.8(MPa). A group index of 0 – 0.8 with an average of 0.17 characterize the quality of these subbase fill soils (tables 4a and 4b).

The compaction results show the optimum moisture content (OMC) to vary from 11.3% – 23.6% with mean of13. 322% while the maximum dry density ranges from 12.3 – 19.2 (KN/m^3) averaging 18.234 (KN/m^3). For materials to qualify for use as subbase fills, Skempton (1953) **[24]** recommends a liquid limit not exceeding 30%, plasticity index less than or equal to 12%, 24 hours soaked CBR at OMC and MDD WASC not less than 30% and a relative compaction of 100%. Specification further recommendation a minimum 15 random samples be tested for a borrow area over 1hectares and the specifications may be modified based on peculiar site specific conditions.

Table 1.0: Summary of subgrade's engineering properties of subgrades

Engineering Property	**Sampling Depth (m)**		**Results of Geotechnical Analysis**		
	Minimum	Maximum	Minimum	Maximum	Average
Natural Moisture Content %	1.0	2.0	11.78	35.30	29.75
Specific Gravity	1.0	2.0	2.44	2.60	2,53
Bulk Density (g/cm^3)	1.0	2.0	1.541	2.61	1.72
Bulk Unit Weight (KN/m^2)	1.0	2.0	15.12	25.60	16.87
Dry Density (g/cm^3)	1.0	2.0	1.253		1.40
Dry Unit Weight (KN/m^2)	1.0	2.0	12.292	16.334	13.734
Liquid Limit %	1.0	2.0	25.70	54.10	27.31
Plastic Limit %	1.0	2.0	8.0	37.00	16.05
Plasticity Index	1.0	2.0	5.0	28.40	14.79
% of Non-plastic subgrades	30.51				
Optimum Moisture content %	1.0	2.0	10.5	19.40	16.06
Maximum Dry Density (KN/m^3)	1.0	2.0	16.75	19.55	18.18
CBR % (48 hours Soaked)	1.0	2.0	7.0	38.00	9.90
Elastic modulus (MN/m2)	1.0	2.0	70.0	380.00	105.2
Subgrade surface modulus Es (MPa)	1.0	2.0	61.5	168.14	68.82
Resilient Modulus (MN/m^2)	1.0	2.0	72.394	392.996	114.88
% Clay	1.0	2.0	0.4	8.00	2.89
% Silt	1.0	2.0	0.6	13.50	5.71
% Fines	1.0	2.0	3.5	19.50	8.68
% Sand	1.0	2.0	8.0	96.40	84.02
% Gravel	1.0	2.0	0.1	87.50	7.32
Clay activity	1.0	2.0	0.8	41.25	11.79
Expansivity	1.0	2.0	4.83	68.90	19.45

Table 2: Subgrade classification

CLASSIFICATION	**SUBGRADE CLASS**		Rating	% Good	% Poor
USCS Classification	CL	CI		41.15	58.85
	% of samples classified as A-2-4	8.930	Excellent to Good		
	% of samples classified as A-2-5	1.800	Excellent to Good		
	% of samples classified as A-2-6	28.57	Excellent to Poor		
	% of samples classified as A-2-7	1.800	Excellent to Poor		
	% of samples classified as A-7-5	3.570	Fair to Poor		
	% of samples classified as A-7-6	35.71	Fair to Poor		
	% of samples classified as A-3	16.10	Fair to Poor		
	% of samples classified as A-6	3.570	Fair to Poor		
Group Index	0	2.9			

4.2 Considerations for Design and Construction

Conservative design of pavement infrastructure is based on classification of subgrade surface modulus which is an estimation of foundation stiffness based on subgrade CBR used for foundation design. The fundamental objective of the pavement foundation is to distribute vehicular loads to the underlying soil formation without causing distress in both the foundation layer and the overlying pavement layers during construction and service life. The fundamental objective of the pavement foundation is to distribute vehicular loads to the underlying soil formation without causing distress in both the foundation layer and the overlying pavement layers during construction and service life. The soaked CBR in the study depicts spatial variations ranging from 7 to 38% depicting medium hard to hard ground condition and subgrade effective modulus of 61.15 – 168.14MPa under class 2-3 of surface modulus classification of pavement foundation Skempton (1953) [**24**] and provides average to good subgrade conditions.

International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 4 Issue 9, September – 2020, Pages: 9-17

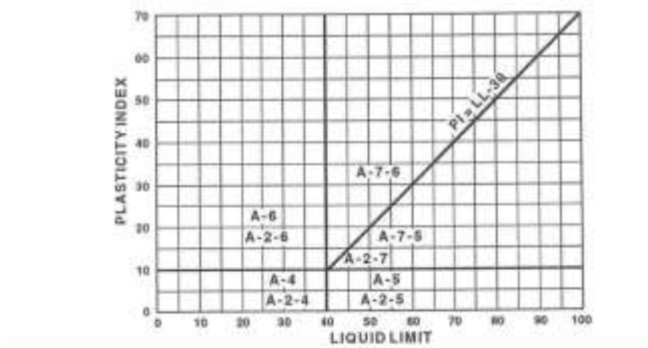


Figure 2: AASHTO Classification of the subgrades/subbase

The thickness of a road pavement depend on the expected traffic volume, strength indexed by the California Bearing Ration (CBR), subgrade modulus, elasticity and resilient moduli of the natural subgrade. The design subgrade strength is the lowest representative value of CBR and subgrade modulus likely to be encountered during the lifespan of the pavement.

The pavement thickness should be based on the subgrade's group index and CBR. Consequently, on the basis of group index and using Fidelis (2019) **[30]** charts, pavement thickness varies from 300 – 350mm plotting in curve D. On the basis of CBR and using design charts provided under road note 29, a thickness of 250 – 300 is recommended.

In consideration of the low lying topography and ground elevation which is below or at par with the sea level in places and the zone being the recipient of the maximum rainfall amount of 2600 – 2800mm annually, pavement infrastructure is perennially submerged and under constant ingress thus increasing the pore water pressure, reducing the effective stress and the shear strength of the subgrades, and the bases, granular subbbases of river sharp sand and gravely materials are recommended.

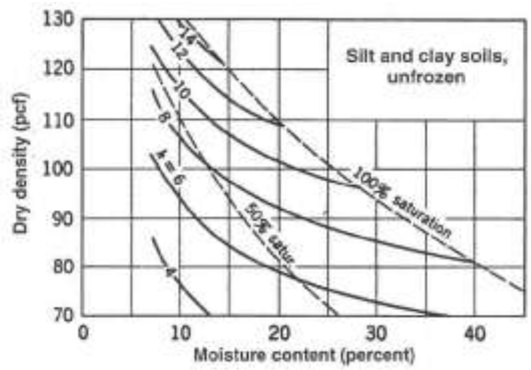


Figure 3: Typical particle distribution curves for the study area

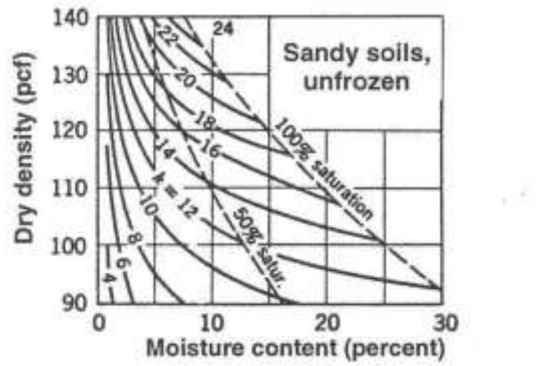
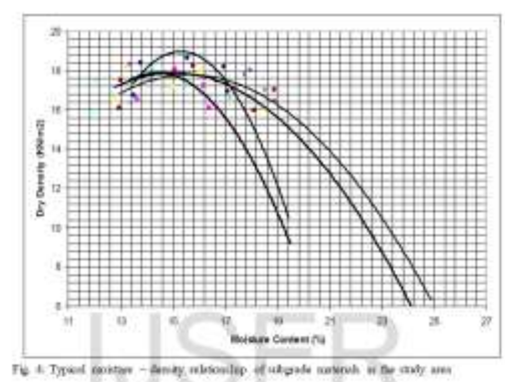


Figure 3: Typical particle distribution curves for the study area

Table 3: Pavement foundation classes based on subgrade surface modulus [after 24].

Pavement foundation Class	Subgrade Surface Modulus
Class 1	≥ 50MPa
Class 2	≥ 100MPa
Class 3	≥ 200MPa
Class 4	≥ 400MPa

Construction should ensure removal of all unsuitable materials to depth and subgrade and subbase layers should be adequately compacted by combination of sheep foot and smooth drum vibratory roller compactors to achieve 100% and 95% compaction in the subbase and subgrade layers respectively to provide for the maximum dry density required for pavement stability and optimal performance.



5.0 CONCLUSION

Pre-design and construction quality assessment serves as a design tool and construction planning and management. In this study the quality of the materials forming the road bed foundation and the fill subbase have been investigated, characterized and results used as aid in planning for sustainable pavement infrastructures. The profile of the soil indicates a top inorganic clay layer (CL) from surface to an average depth of 0.55m, a silty sand layer of low to high plasticity (ML and MH) extending to about 1.1m and poorly graded sand layer (SP) to 2.0m. Particle gradation generally composed of < 2% gravel, 48 - 96% sand, 5 - 34% silt and ≤ 16% clay and classifies as A3, A-7-5 and A-7-6 AASHTO soil groups. With a moisture content that varies from 15.04%

- 35.31%. Under perennial submergence by high flood levels and ingress into pavement layers, road bed deterioration is a frequent occurrence in the region thus necessitation for new design approaches, construction techniques and materials characterization. Consideration for use of coarse granular subbase has been recommended to provide egress routes and insulate the foundation subgrade. Earthworks quality control is further recommended to ascertain adequacy of compaction.

Table 4a: Classification of approved borrow pit sub-base materials

SAMPLE	Depth (m)	W% (%)	Atterberg limits			Particle Size Analysis			AASHTO Classification	RATING
			LL	PL	I_p	% Fines	% Sand	% Gravel		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
Range		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Average		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

Table 4b: Compaction and strength characteristics of approved borrow pits for use as sub-base fill materials

SAMPLE	Depth (m)	Compaction		CBR (%)			Elastic modulus (KN/m²)	Resilient modulus (MPa)	[illegible]	[illegible] modulus (MPa)	Group index	AASHTO Soil group	Rating as sub-base
		OMC (%)	MDD (KN/m³)	[illegible]	Un-soaked	% Reduction in strength							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Excellent to Good
Range		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Mean		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

6.0 ACKNOWLEDGMENT

The writer wishes to thank the following people for their expertise and their willingness to provide valuable insights into the geotechnical assessment of subgrade and subbase quality for the design and construction of road pavement in parts of the coastal section of Kasese District, Western Region, Uganda, and without whose participation, this paper could not have been written:

DTAC and Nigerian High Commission in Uganda:
High Commissioner Extraordinary and Plenipotentiary of the Federal Republic of Nigeria in Uganda
H.E Amb. (Dr) Etubom Nya Eyoma Asuquo
Counsellor/Head of Chancery of the High Commission of the Federal Republic of Nigeria in Uganda
Mr Arojo Jerome Adebayo
Director General Directorate of Technical Aid Corps, Nigeria
Mr. Pius Olakunle Osunyikanmi
Director Programmes Directorate of Technical Aid Corps, Nigeria
Mr Aliyu S. Hamman

KIU-WC Staff:
Dr Lawal Abdul Qayoom Tunji
Dean School of Engineering and Applied Science
Kampala International University - Western Campus (KIU-WC), Ishaka, Uganda
Mr Ismail Adedayo Oyagbola
HOD Civil Engineering Department
School of Engineering and Applied Science
Kampala International University - Western Campus (KIU-WC), Ishaka, Uganda
Dr Tyoden Bala
Senior Lecturer Statistics and Computation Department
School of Environmental Studies
Kampala International University - Western Campus (KIU-WC), Ishaka, Uganda
Ms Auno Hope Stella
Deputy Director Human Resources
Administration Block
Kampala International University - Western Campus (KIU-WC), Ishaka, Uganda

KASESE DISTRICTS:
The Office of the District Chairperson
Kasese District Local Government
KaseseDistrict Office of Information and Tourism
Kasese, Western Region, Uganda

UNRA HEAD OFFICE, UGANDA:
The Office of the Executive Director
Uganda National Road Authority
Plot 3-5 New Port Bell Road
UAP Nakawa Business Park, Kampala, Uganda.

Volunteers and Contributors:
All Authors and journals whose work appeared, Co-Volunteers of Technical Aid Corps, Nigeria (DTAC) and Academic and Non-Academic staffs of the department of Civil Engineering Department and School of Engineering and Applied Science.

7.0 REFERENCES

[1] Li, Q, Mills, L. and McNeil, S. (2011). The implications of climate change on pavement performance and design. A report submitted to the University of Delaware University Transportation Center. UDUTC, Final Report. 54pages Maxwell, J. C. (1892). A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, pp.68-73.

[2] O'Flaherty, C. A. (1997). Evolution of the transport task: C. A. O'Flaherty (ed): Transport planning and traffic engineering. Oxford: Elservier. 544pages.

[3] Kadyali, L. R. and Lal, N. B. (2008). Principles and practices of Highway engineering. New Delhi:Khanna Publishers. 848 pages.

[4] Highway design Manual (2013). Uganda's Ministry of Works and Transport, Pavement and Material design, Vol. III., Uganda, Pp. 1 – 165.

[5] African Journal of Environmental Science and Technology Vol. 5(1), pp. 15 - 24, January 2011 Available online at http://www.academicjournals.org/AJEST ISSN 1996-0786 ©2011 Academic Journals

[6] Uganda's Highway design manual 2009.

[7] Interim Advice Note 73/06, Revision 1 (2009): Design guidance for road pavement foundations. (Draft HD25) pp. 1 – 59.

[8]] Musisi, F. K. S. (2018). Exploring ground conditions for sustainable building foundation design. Proceedings of 1st and 2nd International conferences of the Uganda Association for Engineering Geology and the Environment. Kasese, Vol. 1, pp. 32 – 41.

[9] MOWTC (1992) - General Specifications for Road and Bridge Works, Vol lIIA; GOU).

[10] Robert Ndyabarema; et al. (November 2013). "Bumbobi-Bubulo-Lwakhakha Road: Environment And Social Impact Statement (ESIS) - Updated Final Report November 2013" (PDF). African Development Bank. Retrieved 15 July 2015

[11] NCTTCA (2018). "About the Northern Transportation Corridor". Mombasa: Northern Corridor Transit and Transportation Coordination Authority (NCTTCA). Retrieved 9 June2018.

[12] MOWTC (1992) - Conditions of Contract for Road and Bridge Works, Vol 11; GOU.

[13] UMWT (11 July 2015). "Upgrade of Mbarara – Kikagati – Murongo Bridge (74 Km)". Uganda Ministry of Works & Transport (UMWT). Archived from the original on 12 July 2015. Retrieved 11 July 2015.

[14] Ministry of Works & Transport (2017). "Key Summary Statistics". Kampala: Uganda Ministry of Works and Transport. Retrieved 9 June 2018.

[15] MOWTC (1992) - Tender Documents for Road and Bridge Works, Vols IA and IB; GOU.

[16] Kiggundu, Edris (5 April 2015). "Entebbe–Kampala Highway: What Is Done So Far". The Observer (Uganda). Kampala. Archived from the original on 12 July 2015. Retrieved 15 July 2016

[17] UNRA (19 January 2016). "Upcoming Projects: New Roads for Upgrade to Tarmac". Kampala: Uganda National Roads Authority (UNRA). Archived from the original on 20 January 2016. Retrieved 19 January 2016.

[18] AICPI (April 2013). "Feasibility Study, Detailed Engineering Design, Tender Assistance And Project Management for The Upgrading to Bituminous Standards of Lot A: (i) Rwenkunye-Apac-Lira-Kitgum-Musingo (350 km) And (ii) Olwiyo-Gulu-Kitgum (167 km)". Aicprogetti.it (AICPI). Retrieved 16 July 2015.

[19] Hospers, I. J., 1965, Gravity field and structure of the Western Region, Uganda, East Africa: Geological Society of American Bulletin, Vol. 76, p. 407-422.

[20] Kaplan, A., Lusser, C.U., Norton, I.O. 1994. Tectonic map of the world, panel 10: Tulsa, American Association of Petroleum Geologists, scale 1:10,000,000.

[21] Short, K. C., and Stäuble, A.J., 1965, Outline of geology of Niger Delta: American Association of Petroleum Geologists Bulletin, Vol. 51, Pp. 761-779.

[22] Uganda's Ministry Works and Transport (1997). Uganda General Specification for Roads and Bridges, Revised Edition 2. Pp. 137 – 275.

[23] British Standards Institute (1990).Methods for testing of soils for Civil engineering Purposes, BS 1377, part 4.

[24] Skempton, A. W. (1953). The colloidal activity of clays. Proceedings of the third International Conference of Soil Mechanics and Foundation Engineering, Zurich, 1, 57 – 60.

[25] Sridhara, A. and Prakash, K. (2000). Classification procedures for expansive soils. Proceedings of the Institution of Civil engineers, Geotechnical Engineering, 143 Oct. Pp. 235 – 240.

[26] Charles, R. (2001). Chapter 3: Design of Coastal Roads: A course in Coastal Defense Systems, II. Professional development programme: coastal infrastructure design, construction and maintenance. Department of Civil Engineering, University of the West Indies, in conjunction with Old dominion University, Norfolk, VA, USA and Coastal Engineering Research Centre, US Army, Corps of Engineers, Vicksburg, MS, USA..

[27] Uganda's Ministry of Works and Transport (2000).

[28] GFC (24 January 2016). "Distance between Ntungamo, Western Region, Uganda and Rukungiri Court, Rukungiri, Western Region, Uganda". Globefeed.com (GFC). Retrieved 24 January 2016.

[29] Steele, D. J. (1945). Application of classification and group index in estimating desirable subbase and total pavement thickness. Proceedings, Highway Research Board, Pp. 388 – 392.

[30] Fidelis Ankwo Abija (2019) Geotechnical assessment of subgrade and sub-base quality for the design and construction of road pavement in parts of the coastal section of Akwa Ibom State, Eastern Niger Delta, Nigeria. International Journal of Scientific & Engineering Research Volume 10, Issue 7, July-2019 ISSN 2229-5518 1877 IJSER © 2019 http://www.ijser.org ijser