

ASSESSING THE SUITABILITY OF BEACH SAND FOR ROAD CONSTRUCTION

DAILESI ABDUL-AZIZ GULANI

(ESC-012-20)

Thyolo, Malawi

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DISSERTATION APPROVED BY:

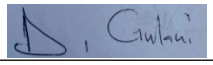
SUPERVISOR: Mr. T. Shaba Signature T. Shaba

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ABSTRACT

Sand, an important fine aggregate material for mortar and mortar mixtures, plays a crucial role in construction, and its quality significantly affects the performance of buildings. Being a product of weathering and sedimentation, sand parameters will vary in their properties from one area to another. This dissertation presents a comprehensive assessment of beach sand for road construction in Monkey Bay, Mangochi. This area is characterized by different geological formations comprising basement complex rocks, including high-grade paragneisses and charnockitic granulites. This area is dominated by monazite-bearing beach sand and other minerals, including biotite-hornblende-quartz-syenites (indicative of post-orogenic, high-level types) and biotite granite (Kalk et al., 2012b).

The study aimed at evaluating the grain size uniformity, organic impurities, and mineral composition of sand samples from various beach sites within Monkey Bay to determine their suitability for road construction. A purposive methodology was employed, involving the collection and analysis of sand samples from beach locations. All tests were conducted at the Malawi University of Science and Technology geology laboratory. The tests followed the standards set by the American Society for Testing and Materials (ASTM) of 2007, which acted as benchmarks for evaluating the sand quality.

Grain size distribution analysis was accomplished by sieving the sand samples, organic impurity assessment used a mixture of sand samples with sodium hydroxide, and mineralogy of the sand was accomplished by hand lenses, with all tests following the ASTM procedures. From the results, there is variability in terms of grain size distribution from different locations, with some samples falling short in the required distribution, which could affect the consistency and strength of road structure. Organic impurities too had varying concentrations in different samples, with others exceeding the recommended standard, while the mineralogy showed a dominance of durable minerals of quartz and feldspar with varying little amounts of weak, flaky minerals, mostly mica.

The study concludes that Masasa 1, Masasa 2, and Malabwe beach sand generally meet quality standards for road construction. However, there is a need for modification of Malabwe sand since it has exceeded the organic impurity limit required for the road construction. Finally, the study recommends that all the beach sand can be used for road construction; it also underscores regular quality checkups and treatment of sand before commencement of road construction projects to prevent deleterious effects that unsuitable sands can cause. Further tests have been encouraged to add to the quality of the sand based on the available findings.

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1. CHAPTER 1: General Introduction

1.1 Background

Road construction leads to social development, enabling connectivity and enhancing economic growth. The materials used for road construction influence infrastructure durability and sustainability (Lechner et al., 2020). Aggregates used for road construction must meet certain standards as they directly impact durability, workability, and quality consistency—critical factors that determine whether the road will be strong, long-lasting, and cost-effective ('Long-Life Surfaces for Busy Roads,' 2008).

Sand is a granular material that resulted from the weathering of silicious rocks and is mainly composed of silica in the form of quartz (Lay, 2009). According to Nemati & Tahmoorian (2020b), for Southern African roads and European roads, the minimum size of sand is 0.075 mm (No. 200 mesh sieve). However, very few sands contain materials that solely fall within this range, being either smaller (<0.075 mm) or larger (>2 mm).

Over the past years, rapid urbanization along with infrastructure development and population growth has caused a rise in demand for construction materials (He et al., 2021). The UN environment report shows that global demand for sand and gravel reaches approximately 40-50 billion tons per year, with 13.7 billion tons of sand mined worldwide for construction purposes in 2016 alone (UNESCO, 2021; Croitoru & Sarraf, 2010). This extraction, particularly from rivers, leads to pollution and the lowering of water aquifers (UNESCO, 2021).

In many Southern African Development Countries (SADC regions), good-quality road construction materials are already depleted (The official SADC Trade, Industry, and Investment Review, 2005). However, previous studies show that beach sand closely aligns with standard specifications (ASTM and AASHTO) (Maadani, 2015). Based on these findings, a recommendation was made to assess the performance of road construction aggregates made from beach sand.

1.2 Study Area

Monkey Bay town lies at the southern end of Lake Malawi in the Mangochi district. It is situated between latitudes 14°00′S and 14°30′S and longitudes 34°30′E and 35°00′E. The area is primarily underlain by the basement complex rocks, including high-grade paragneisses and charnockitic granulites. This area is dominated by monazite-bearing beach sand and other minerals, including biotite-hornblende-quartz-syenites (indicative of post-orogenic, high-level types) and biotite granite (Kalk et al., 2012b).

A detailed assessment conducted by the Atomic Energy Division of the Geological Survey of Great Britain in 1956 identified significance deposits of these sands; Nkope 1,200 short tons, Chikowa 1500 short tons and Lungu 2700 short tons. The area has undergone significant tectonic activities, with the Rift Valley Escarpment being the dominant structural feature. (Geological survey bulletin)

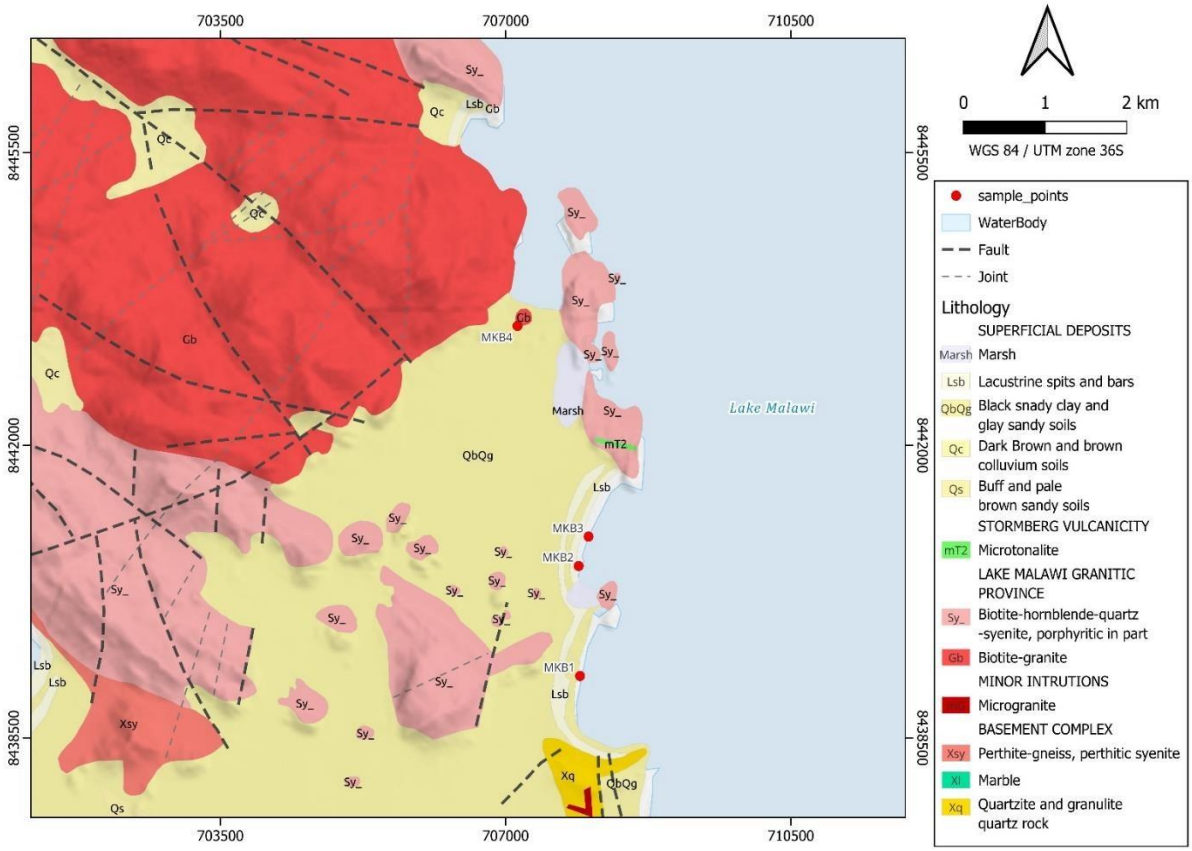


Figure 1 Geological Map of Monkey-Bay

1.3 Problem Statement

The Malawi transport system is dominated by roads which carry more than 70% of internal freight and close to 90% of international freight traffic according to Malawi (Lall et al., 2017). This heavy reliance on road infrastructure underscores the critical need for sustainable and durable road construction practices to support national economic development and regional connectivity (Education & Unesco, 2021b).

Current road construction projects throughout Malawi and neighbouring regions rely heavily on inland quarries for sourcing materials like crushed rocks, gravel, and sand. These traditional sources are facing increasing pressure due to rapid urbanization, population growth, and infrastructure development, leading to resource depletion, environmental degradation, and rising material costs. The Southern African Development Community (SADC) has reported that good-quality road construction materials are becoming scarce in many member countries. (Garrard, 2017).

Previous studies show that one of the main factors for road failure is reduced strength and durability due to the properties of aggregates used for construction. (Bauer et al., 2023).

Despite the abundance of beach sand along coastal regions globally, including Lake Malawi's extensive shorelines, its potential as an alternative material for road construction remains largely unexplored (Lay, 2009). Preliminary assessments suggest that certain beach sand compositions may closely align with ASTM and AASHTO standard specifications required for road construction materials. However, comprehensive research on the engineering properties, performance characteristics, and long-term durability of beach sand in road applications is lacking (Robinson & Thagesen, 2004).

Studying the suitability of beach sand for road construction could diversify material sourcing options, potentially reduce extraction pressure on inland resources, and improve the availability of construction materials. Such innovation would directly support Malawi Vision 2063's infrastructure development goals, which aim at upgrading all roads to world-class national and regional motorways

1.4 Main and Specific Objectives

The main objective of this research is to assess the suitability of beach sand for road construction

1.1.1 Specific Objectives include;

- Assess the uniformity of grain size of the beach sands
- Assess organic impurities in the beach sands
- Analyse the mineralogy of the beach sands

1.5 Research Questions

- How uniform is the grain size of beach sand samples, and does it meet road construction requirements?
- How do organic impurities in beach sand affect its performance in road construction?
- What minerals compose the beach sand, and how do they influence its engineering properties for roads?

1.6 Significance of study

Assessing the suitability of beach sand for road construction is of great importance in many ways. From economic perspective, identifying beach sand as alternative construction material could dramatically reduce costs associated with aggregates procurements. Environmental benefits are equally compelling as utilizing beach sand could reduce dependence on conventional quarrying and mining activities than often result in Habitat destruction, landscape alterations.

This research also has technical significance in expanding beach sand's engineering properties, potentially opening new applications beyond road construction.

From a resource management standpoint, with traditional construction aggregates becoming increasingly scarce or difficult to extract in many regions, this research contributes to resource diversification strategies essential for sustainable development. Furthermore, the establishment of comprehensive quality standards and specifications for beach sand in construction applications would enhance roads infrastructure safety and durability, ensuring that any alternative materials meet rigorous performance requirements.

2. CHAPTER 2: LITERATURE REVIEW

2.1 Sand as Aggregates

Sand is naturally occurring granular material composed of fine rock particles. Its particles range from 0.063 mm to 2 mm in diameter (Panchuk, 2021). This particle size range distinguishes sand from coarser material like gravel and fine materials such as silt and clay (Blott & Pye, 2012).

Sand originates from the weathering and erosion of rocks, which involves the breaking down of large rock particles to small particles for an extended period of time (Allen, 2017).

Geologically, sand is classified based on its mineral composition, with silica (quartz) being the most common sand in many regions. Other types of sand include river sand, deposited by river streams; beach sand formed by the action of waves and currents; pit sand; and dune sand in desert regions.

2.2 Main properties of sand as aggregates

Sand, as a crucial aggregate in construction, has several key properties that determine its suitability for various applications. These properties include particle size distribution, which significantly impacts sand gradation and thus the workability and strength of mixtures like concrete and mortar; the shape and texture of sand grains, ranging from angular to rounded, influencing the interlocking and bonding characteristics; its composition, primarily composed of silica but potentially including other minerals, affecting its chemical stability and hardness; specific gravity, which is essential for calculating the quantity of materials and proportions of mixtures and cleanliness, referring to the absence of organic matter, which can compromise the integrity of construction materials(Wang, 2016).

2.3 Uses of beach sand

Sand, particularly beach sand, serves a remarkably diverse range of purposes. In construction, it is a foundational material used for making concrete, mortar, and asphalt, which are the cornerstones of modern infrastructures like roads and bridges (Nemati & Tahmoorian, 2020b).

Beach sand also plays a vital role in land reclamation projects, where it's used to create new landmasses from bodies of water, expanding coastal areas and providing valuable space for development. Beyond construction, sand is also used in the manufacturing of glass. Recreationally, beach sand provides the perfect medium for activities like beach volleyball and sandcastle building.

The extraction of sand can cause environmental damage, so sustainable practices are needed, and also when considering beach sand for construction, the high salt content must be addressed through washing and processing to prevent damage to the constructed materials.

2.4 Quality of sand for road construction

Different standards were put in place for road construction processes. Different materials must meet these standards for it to be worth using. Quality of beach sand can be defined as how good the sand being used for construction is when compared to road construction standards. Sand is the most aggregate used largely in asphalt mixing and mortar. Its properties greatly affect the road infrastructure. Aggregates used for construction are said to be graded in size, durable, strong, hard, and free from impurities (Grid-Geneva, 2019).

In alignment with the American Society for Testing and Material (ASTM D448-12-2022) Standards

- The gradation for sand for road and bridge construction must be within the limits given in the table below.

Sieve Size (mm)	Percentage passing (%)
4.74	95-100
2	80-100
1	50-85
0.425	25-60
0.25	5-30
0.106	0-10

Table 1 Standard Sieve Sizes and Percentage Passing

- When sand is passed through the series of sieves (with progressively small opening), no single sieve should retain more than 45% of the beach sand. This is to ensure proper gradation. The fine modulus (FM) of fine aggregates must be between 2.3 and 3.1

Lower FM (2.2–2.6): indicates fine aggregates (fine sand)

Medium FM (2.6 – 2.9) medium sized aggregates (medium sand)

Higher FM (2.9–3.1) coarse aggregates (coarse sand)

The FM helps to ensure the aggregates has the right balance of fine and coarse particles for optimal in road construction.

- Based on ASTM C40, the color comparison (colors 1, 2, or 3 being accepted) is widely accepted method to determine if the aggregates are suitable for use

in road construction. Therefore, when tested for organic content, the color should match color 1, 2, or 3 of organic impurity chart shown below

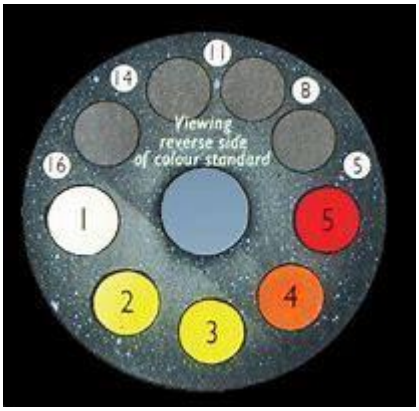


Figure 2 Organic Impurity Chart. Source: ASTM revised (2022)

- The specific gravity should be within this range; 2.5 – 2.8 for fine aggregates and 2.6 – 2.9 for coarse aggregates with less than 2% of the absorption value.

- For high quality fine aggregates, its mineralogy should consist of quartz with minor amount of felspar and calcite. This mineral composition contributes to strength, durability and chemical inertness.

Harmful minerals like clay, mica and reactive silica should be avoided.

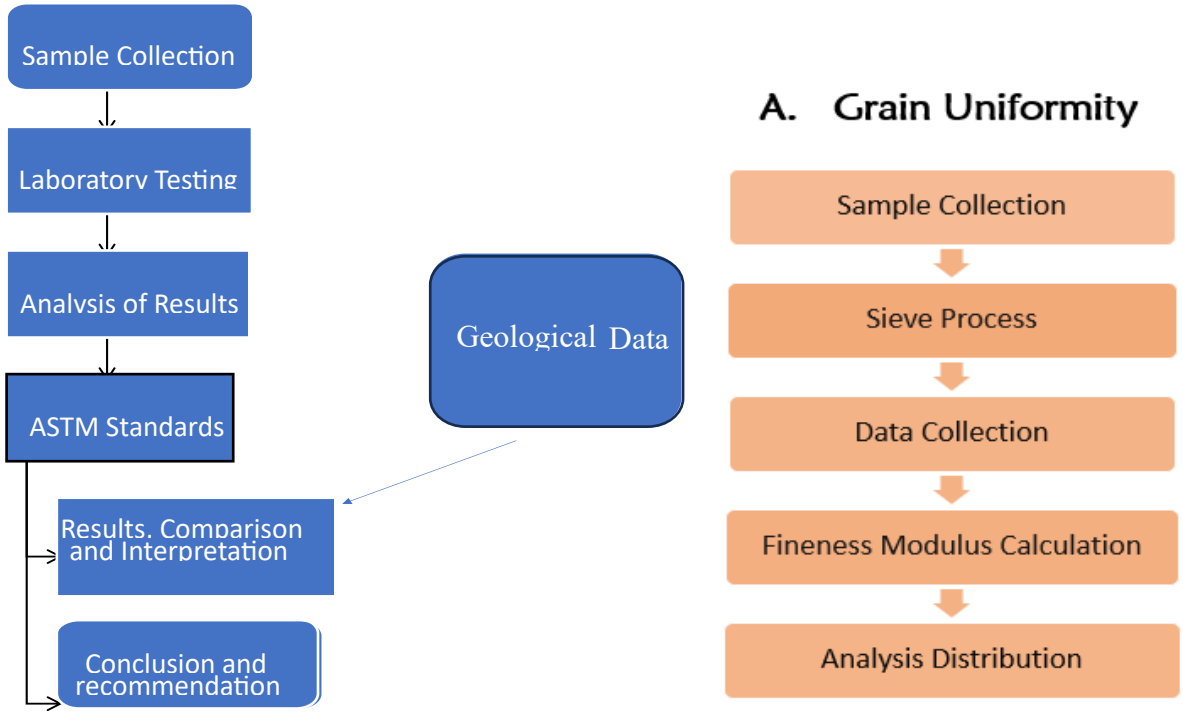
3. CHAPTER 3: METHODOLGY

3.1 Research Design

The research used samples collected from beaches along the shorelines as its primary data. These samples were analyzed in the lab for physical and chemical properties. All results were systematically compared against established road construction standards to determine compliance.

Secondary data from geological studies and relevant engineering literature complemented the primary analysis. This provided context on the regional sand formation process and previous applications in construction.

Statistical analysis of the findings employed both descriptive methods to characterize beach sand properties and inferential techniques to determine the statistical significance of variations between samples and their correlation with the standard road construction materials. Based on these analyses, conclusions were drawn regarding the suitability of beach sand for road construction applications with specific recommendations for potential modifications or optimal usage.



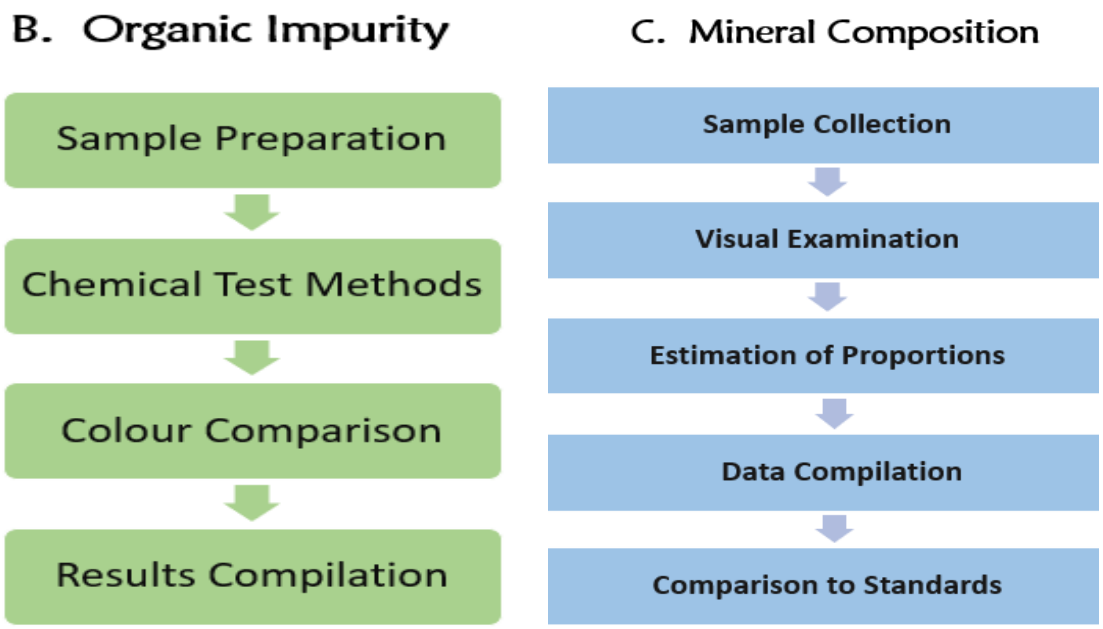


Figure 3 Research Design

3.2 Sampling

Non-probability sampling techniques called judgmental/purposive techniques were used in selecting sample points. One sample at each location. Samples were collected 20m-30mm away from the shoreline at a depth of 100cm.

This provides more stable, representative, and less contaminated samples, which is essential for accurate scientific analysis.

The sampling targeted 3 beaches in Monkey Bay with a large amount of sand, which includes Malabwe, Masasa, and Lake Service. Samples were packed in plastic bags and labeled, ready for lab analysis.

3.3 Materials and Methods

Materials used include sample bags for collecting samples, beach sand samples, sieves and sieve shaker shovels, water, sodium hydroxide, hand lenses, a handheld GPS machine, an organic impurity chart, and Microsoft Excel for analyzing results.

American Society for Testing and Material (ASTM, revised 2022) standards were used as a reference for testing different beach sand parameters in the laboratory.

3.3.1 Sieve Analysis Assessment

Sieve analysis was conducted on the samples from different locations following ASTM D448. The testing was carried out using a U test and a shaker manufactured by Endecotts, London.

The following steps were followed when conducting sieve analysis:

- 5 sieve sizes were used (37.5mm, 25mm,12.5mm4.75mm and 2.36mm)
- Weight of 500g was used for each sample and were dried (at 105˚c-110˚c) and allow it to cool
- The samples were shaken for 10 minutes using sieve shaker
- Average of 3 trials was recorded
- The weight of the materials retained on each sieve was recorded. Percentage retained, cumulative percentage retained, cumulative percentage passing each sieve and the fineness modulus (FM) were all calculated. The following are the formulars;

  Weight retained on a sieve = (weight of sieve + sand) – (Weight of sieve)

  Percentage passing = (wt retained on a sieve ÷ Total wt of the sample) × 100

  Cumulative Percentage retained on a sieve = (Percentage retained on the sieve + Percentage retained from previous sieve(s))

  Cummulative Percentage passing retained on each sieve

  = (100% - Cumulative Percentage retained on the sieve)

Fineness Modulus (FM):

(Calculated for the fine aggregates used for concrete, the applicable sieves are 4.75, 2.36, 1.18, 0.600, 0.300 and 0.500)

$$FM = \frac{\sum \text{cumulative percentage retained on the sieves}}{100}$$

3.3.2 Assessment of Organic impurities

The presence of organic impurities in aggregates, especially natural sand, affects the setting time and hardening of concrete and may also cause deterioration of concrete and pop-outs.

The primary chemical test method was conducted following ASTM C40.

- The weight of the sample from each sample point was 450 g.
- The calibrated glass bottle of volume 130 ml was filled with dry sample sand.
- Sodium hydroxide solution was added until the total volume of sand and the solution reached 200 ml.
- The bottle was sealed, shaken vigorously, and left to stand for 24 hours.
- The colour of the resulting liquid above the sand is compared to the standard colour chart.

3.3.3 Mineralogy of the beach sand samples.

- The mineral constituents in the sand were determined by analysing samples under hand lenses in the laboratory.
- For identification purposes, sand was placed on white paper and examined using a hand lens to magnify the grains.
- Based on the observations made during examination, the proportions of different minerals present in the samples were estimated.

3.4 Data Analysis

Data analysis consisted of comparing experimental results against established standards to comprehensively evaluate the sand qualities while also correlating the sand characteristics with local geological features documented in existing literature. Following data collection, Microsoft Excel served as the primary analytical tool, enabling the processing of data and the creation of visual representations such as tables, graphs, curves, and charts that effectively illustrated the study's findings. The comparative approach established meaningful correlations between mineralogical composition and physical properties, ultimately allowing for the development of quality metrics based on deviations from standard specifications to determine the suitability of different sand samples for road construction applications.

3.5 LIMITATIONS OF STUDY

When conducting the sieve analysis, the following sieve sizes were supposed to be used: 4.75mm, 2.36mm, 1.16mm, 0.6mm, 0.3 mm, and 0.15mm. However, this did not happen due to the unavailability of these sieve sizes in the laboratory, but instead the following sieves that are close to the above sizes were used: 4.74mm, 2.0mm, 1mm, 0.425mm, 0.25 mm, and 0.106mm.

In the same sieve analysis, the sand samples were supposed to be dried in an oven at a temperature of 110°C ± 5°C for the sample to reach a constant mass. This did not happen due to the unavailability of an oven in the laboratory. Instead, the samples were sun-dried for 24 hours.

The specific gravity was one of the specific objectives supposed to be achieved during the analysis, but this did not happen due to the unavailability of materials that are used for this analysis of specific gravity.

4. CHAPTER 4: RESULTS AND DISCUTION

4.1 RESULTS

4.1.1 Organic content in the sand

The data from these locations reveals significant variability in organic content across different sample points (Masasa 1, Masasa 2, and Malabwe). The samples from Malabwe indicate the highest presence of organic materials, exceeding the acceptable limit. Meanwhile, samples from Masasa 1 and Masasa 2 meet ASTM C40 standard requirements. The image and table below display the samples and corresponding observations, respectively.



Figure 4 Results of organic impurities in the sand

Sample ID	Results Plate No. And Colour	
Malabwe	4	Dark amber/ brownish orange
Masasa 1	3	Light brown
Masasa2	2	Light yellow

Table 2 Showing Observed colors results of organic Impurities in the sample

4.1.2 Mineral Composition

The sample points have almost similar mineral composition. All the sand is composed largely of quartz, feldspar, and a small amount of mica. The analysis was done using a hand lens, where the grain sizes were clearly seen. The results from sieve analysis as well perfectly separated grains according to sizes, making it easier to analyse. The charts below show the proportion makeup of all three sites.

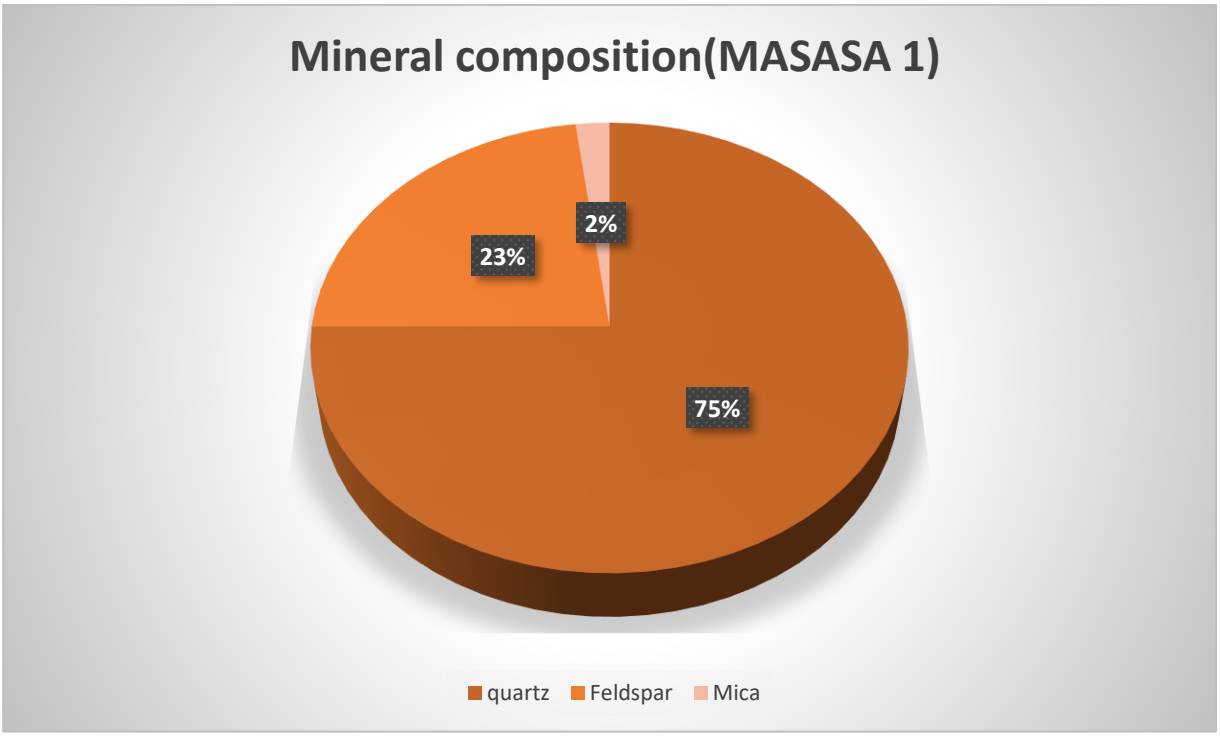


Figure 5 Showing Mineral Composition of Masasa1

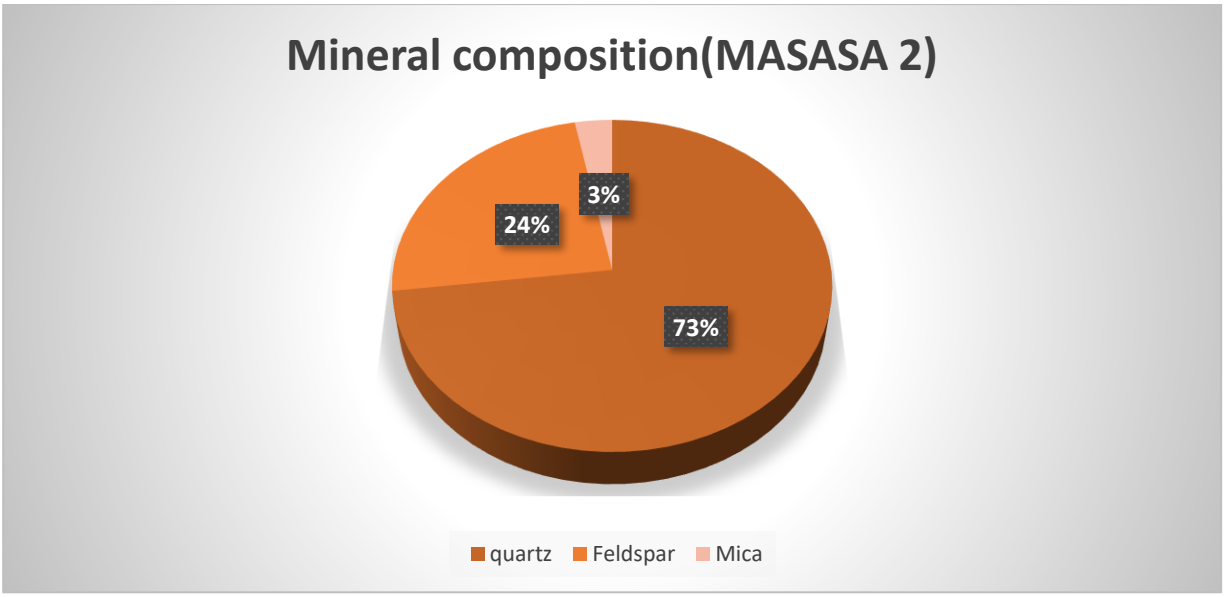


Figure 6 Showing Mineral Composition of Masasa 2

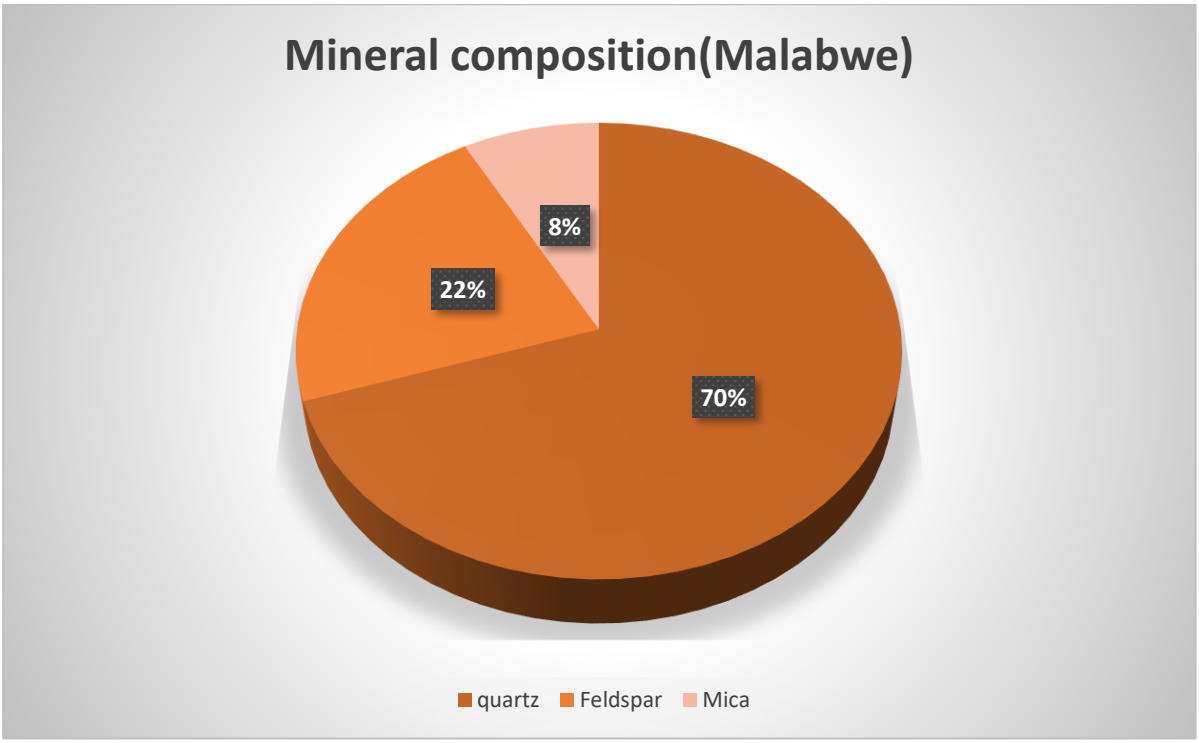


Figure 7 Showing Mineral Composition of Malabwe

The mineral composition of sand greatly impacts the quality of road construction, with quartz-rich sand providing high strength and durability due to its hardness and chemical stability, while problematic minerals like mica create weak planes and reduce workability. Feldspar content may lead to weathering over time. The mineral composition differs due to different geological factors. The parent rock type fundamentally determines the type of minerals available. The weathering process involves the breaking down of stable minerals while resistant ones like quartz stay intact. Transportation mechanisms (water, wind, and glaciers) and also depositional environments (beach, river, desert) further influence composition through sorting and chemical interaction. From the sample locations, Masasa 1 and Masasa 2 have almost similar mineral composition since the location is the same; the only difference is grain uniformity of the sand. The third sample point (Malabwe) has a different mineral composition compared to the two, as it has a higher amount of mica. This can be due to low energy deposition. The low energy deposition tends to favor mica preservation, as high-energy environments tend to break down or transport away these soft minerals.

4.1.3 Grain Sizes

The gradation of sand varies in all beaches from where the samples were collected. 1000g were used for the analysis in all the samples. The following graphs show the results from all the sample sites, starting with Malabwe.

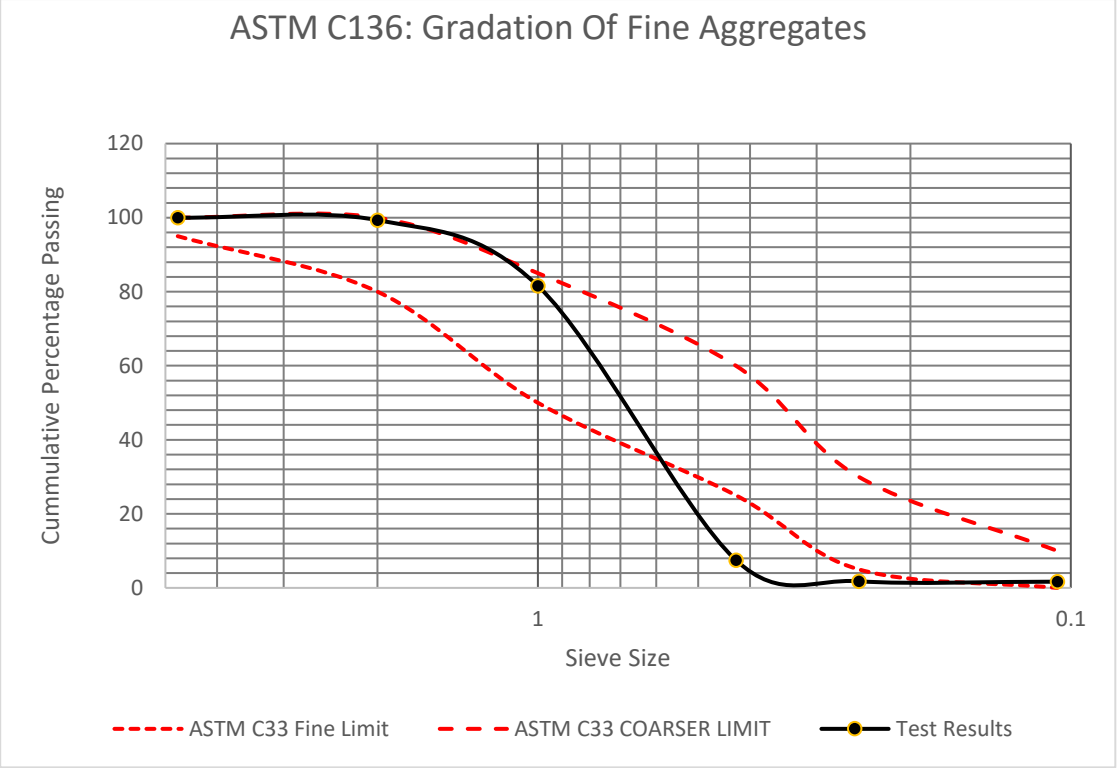


Figure 8 Graph showing Gradation of sand from Malabwe beach

From the graph, it shows that all the materials passed through the larger sieve (4.74mm). There is a steep gradation curve between 1.00mm and 0.25 mm, indicating a significant drop-off in the percentage of materials passing through these intermediate sieves. Upon calculating, the sand sample has a fineness modulus of 3.08.

Second results are from Masasa beach sand:

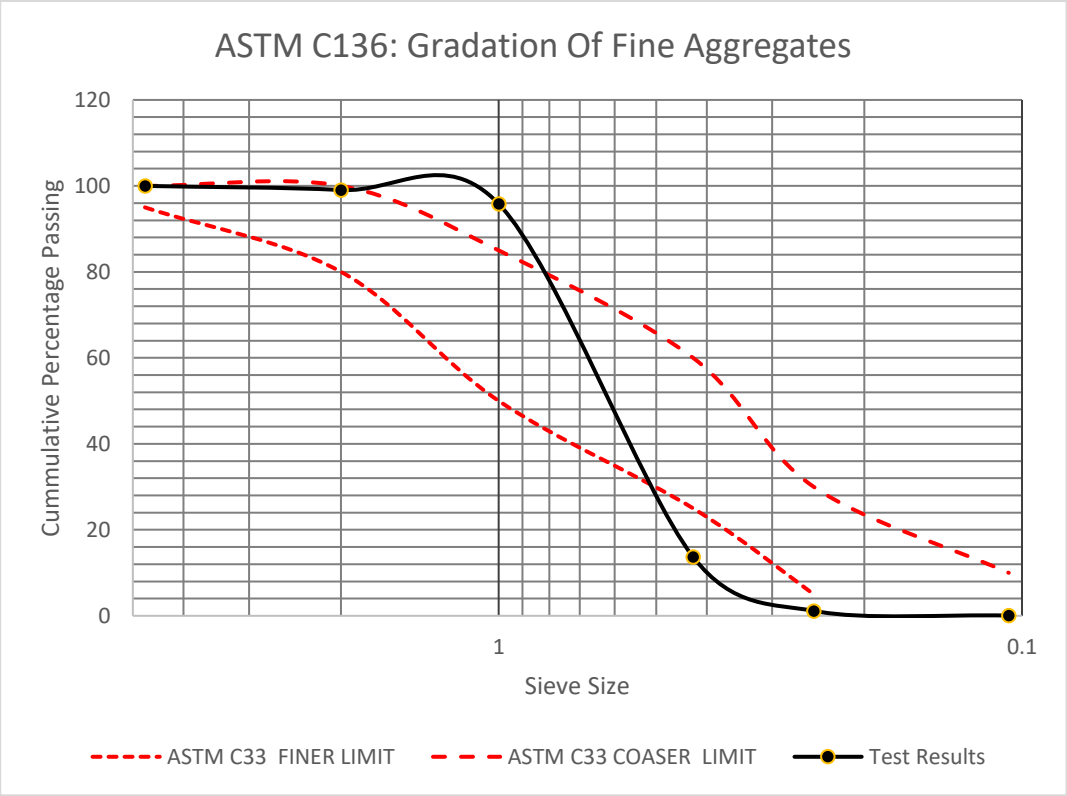


Figure 9 Graph showing gradation of sand from Masasa 1 beach sand

The graph shows a consistent descending trend; nearly 100% of the material passes through larger sieves, a steep decline occurs in the mid-range indicating a good distribution of particle sizes, and the percentage levels off towards 0% at smaller sieves. The fineness modulus of this sample was calculated, and it is 2.9.

Third sample from Masasa 2:

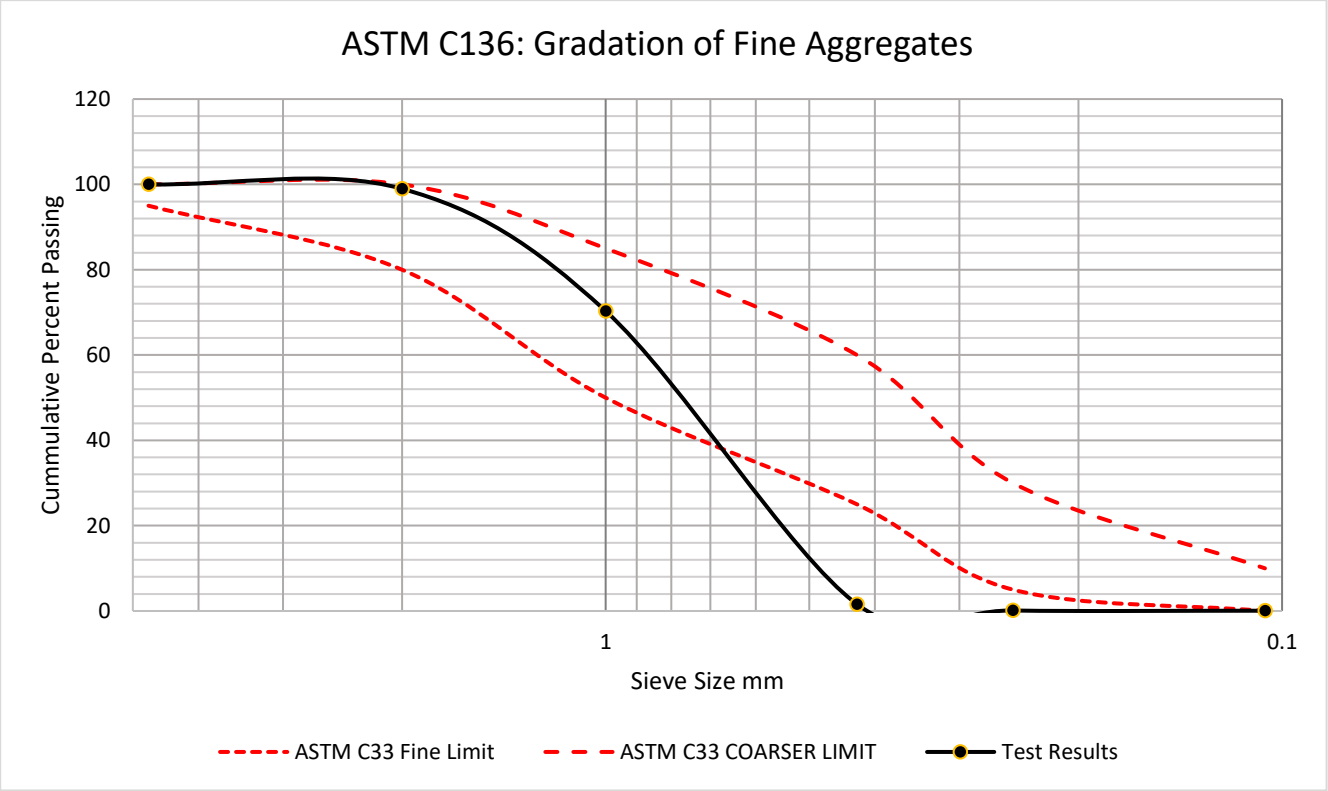


Figure 10 Graph showing gradation of sand from Masasa 2

The graph depicts a rapid decrease in the amount of sand passing through the second sieve, following near-complete passage through the first. Subsequent sieves showed a more gradual reduction; this trend reversed at the smallest sieves. The fineness modulus for this sand is 3.3.

4.2 Discussion

4.2.1 Organic content

Another important component that determines the quality of sand suitable for construction is organic contents. They can be found in a variety of places, including dead insects, plants and products, and animal carcasses and their byproducts. Their displays differ significantly based on where majority of them have been deposited. The findings indicate that organic impurities were present in all samples in varying levels. However, the sand from the Malabwe beach has a high concentration of organic impurities.

The table below helps in interpreting the findings from the sample solution to determine the concentration of impurities in the sand and check if they meet standards.

Sample ID	Colour No.	Standard Limit	Pass/Fail
Masasa 1	2	3	Pass
Masasa 2	3	3	Pass
Malabwe	4	3	Fail

Table 3 Showing Results and Standard limits for organic Impurities

From the results, samples from Masasa Beach 1 and 2 are both within the acceptable limits of the organic impurities, whereas samples from Malabwe Beach show a lot of organic impurities. This could be due to human activities, as this place is used for recreational activities.

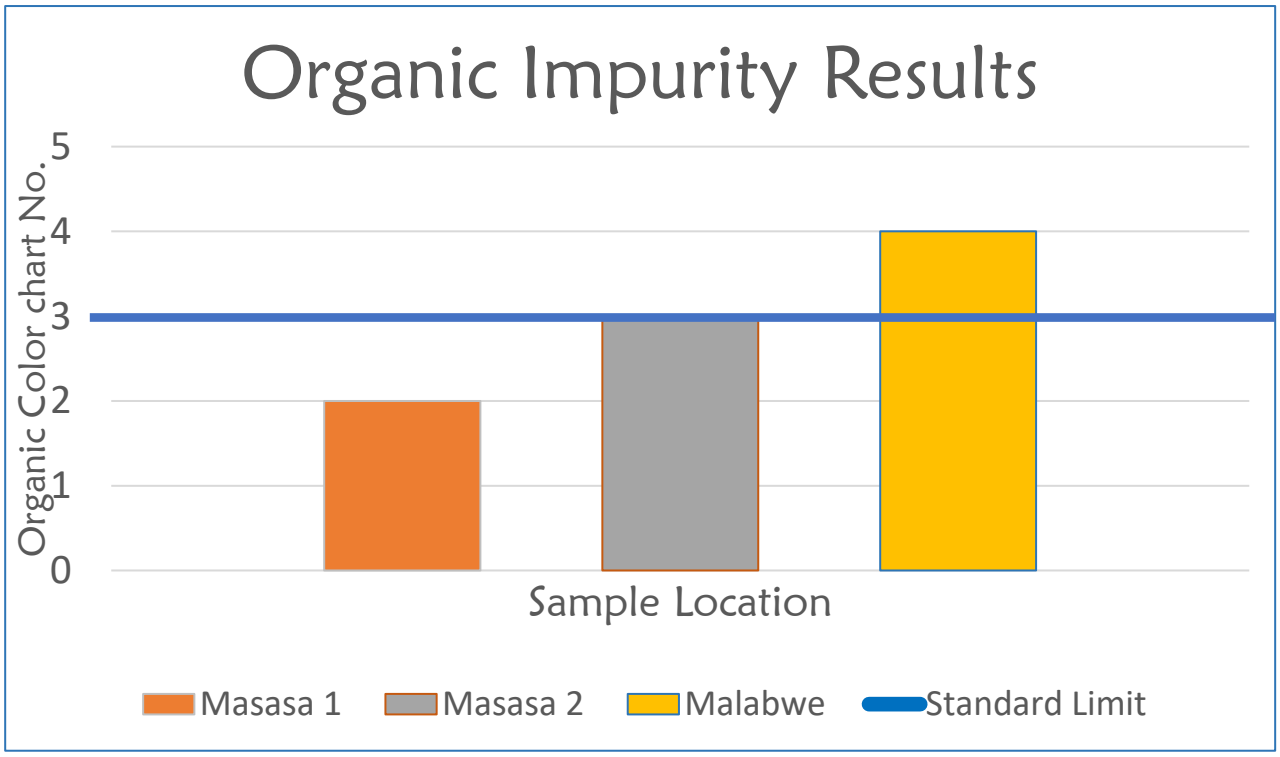


Figure 11 Graph showing organic impurity results

4.2.2 Grain Sizes

The sieve analysis helps grade the sand in various particle sizes present in that particular sample, thus ranging from coarse to fine sizes. From the results of the percentage of passing, a fineness modulus is obtained, showing the average particle size of the sample. Generally, from the graphs, almost all samples have a good gradation, as most of them fall within the limits of the pass rate. However, the ASTM C136 gradation graph for fine aggregates reveals that the tested sand sample (Malabwe sample) generally follows the ASTM C33 coarser limit for larger particle sizes between 5 and 1 mm, but then drops more sharply below the 1 mm sieve size. The sample shows a deficiency in the medium-to-fine particles, particularly in the 0.5-0.2 mm range, where it falls below the coarser limit boundary, and contains very few particles at the 0.1 mm size, with nearly 0% passing. This indicates a gap-graded material with an abundance of coarser particles and insufficient finer fractions. While the sample generally remains within the overall ASTM C33 boundaries defined by the upper and lower limits, its close proximity to the coarser limit throughout most of the curve suggests a relatively coarse sand that may impact workability, water demand, and finishing characteristics when used in concrete mixtures.

The result from sample point 2 (masasa 1) shows similar test results but with some information. The fineness modulus (FM)of the sand is 2.9, which is within the typical range for concrete sand (2.3-3.1). The test results demonstrate a gradation that follows close to the ASTM C33 coarser limit at larger sieve sizes, and shows an even more pronounced drop between the 1mm and 0.5mm sieves. This creates a steeper curve that crosses from near the upper limit to below the lower limit in the mid-range particle sizes. The sample contains very few particles in the finest fraction (0.1mm), with the curve flattening near zero percent passing. The relatively high fineness modulus (2.9) confirms this is a coarser sand.

The results from the third sample point (Masasa 2) show a similar pattern to the previous graph. The test results indicate approximately 100% of material passing at the larger sieve sizes (near 4.74mm), maintaining close to 100% passing at the 2mm sieve, then dropping more significantly below the ASTM C33 coarser limit at around 1mm. The curve shows a steep decline between 1mm and 0.5mm, reaching nearly 0%

passing at around 0.3mm sieve size, with essentially no material passing the smaller sieves. This gradation confirms that Masasa 2 sand is predominantly composed of coarse particles with a severe deficiency in medium and fine fractions. The curve falls outside the ASTM C33 acceptable envelope at the smaller sieve sizes, dropping below even the finer limit curve. This gap-graded material would likely produce concrete with poor workability, harsh finishing characteristics, and potential segregation issues. The sand would require blending with finer materials or significant mix design modifications to produce workable and durable concrete mixtures.High fineness modulus (3.3) confirms this is a coarser sand.

4.2.3 Mineral Composition

The mineral composition of sand affects the quality of the road construction, with quartz-rich sand providing strength and durability due to its hardness and chemical stability, while problematic minerals like mica create planes of weakness. Feldspar content may lead to weathering over time. The mineral composition differs due to differences in geological factors. The parent rock type determines the availability of minerals. The weathering process, which involves breaking down stable minerals while resisting ones like quartz, remains intact. Transportation mechanisms (water, wind, and glaciers) and also deposition environments (beach, river, and desert). From the sample locations, Masasa 1 and Masasa 2 have almost similar mineral compositions since the location is the same and the only difference is the grain uniformity of the sand. The third sample point (Malabwe) has a different mineral composition compared to the other two, as it has a greater amount of mica. This can be due to low energy deposition. The low-energy deposition environment tends to Favor mica preservation compared to the high-energy deposition environment, as it breaks and transports away these soft minerals, mica.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

The aim of the study was to assess the suitability of beach sand from monkey bay site for road construction by comparing with different standards.

5.1 CONCLUSION

5.1.1 GRAIN SIZE

Sieve analysis was used to show the variations of particle sizes of the sand. Samples were collected from four sites, but only three sites samples were analysed in the lab by conducting three analyses, which are sieve analysis, mineral composition, and organic impurities in the sands. From the results obtained, it was found that the grain sizes were almost similar from all the sample points (Malabwe, Masasa 1, and Masasa 2). When these results were compared to the ASTM standards, it revealed that all the sand from all sample points has excellent grain sizes suitable for road construction, with fineness moduli of 2.9 for Masasa 1, 3.3 for Masasa 2, and 3.08 for Malabwe, respectively. This indicates medium to high coarse sand for Masasa 1 that falls within the normal range for the road construction material standards. Using this type of sand will increase the workability and longevity of road construction projects.

5.1.2. Determination of Organic Content

All the samples indicated the presence of organic impurities; however, the concentration of these impurities is high for Malabwe samples, making it unfavourable for the road construction projects, as it may affect the road structure. While Masasa 1 and Masasa 2 are the samples, they are within the acceptance range as shown in the graph for organic impurities in the discussion section above.

5.1.3. Determination of Mineral Composition

This objective was looking at the mineral constituents within the sand. All places show huge compositions of hard minerals (quartz and feldspar), which are good for construction. However, the sample from Malabwe shows a slight increment of mica and other microscopic minerals.

5.2 RECOMMENDATIONS

According to the findings of this study, the following recommendations are made:

I. There is a need to conduct modification before use on the Malabwe beach sand. The modification can involve chemical treatment to oxidize organic matter.

II. The sand samples from all sites can be used as aggregates for road construction as they meet different ASTM standards.

III. More tests should be carried out on the suitability of beach sand, and this can include:

- Specific Gravity
- Bulk density
- Moisture content

IV. Environmental impacts for the extraction of beach sand for road construction should be undertaken.

V. Further studies on the suitability of beach sand should be carried out across all beaches in Malawi.

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APPINDECES

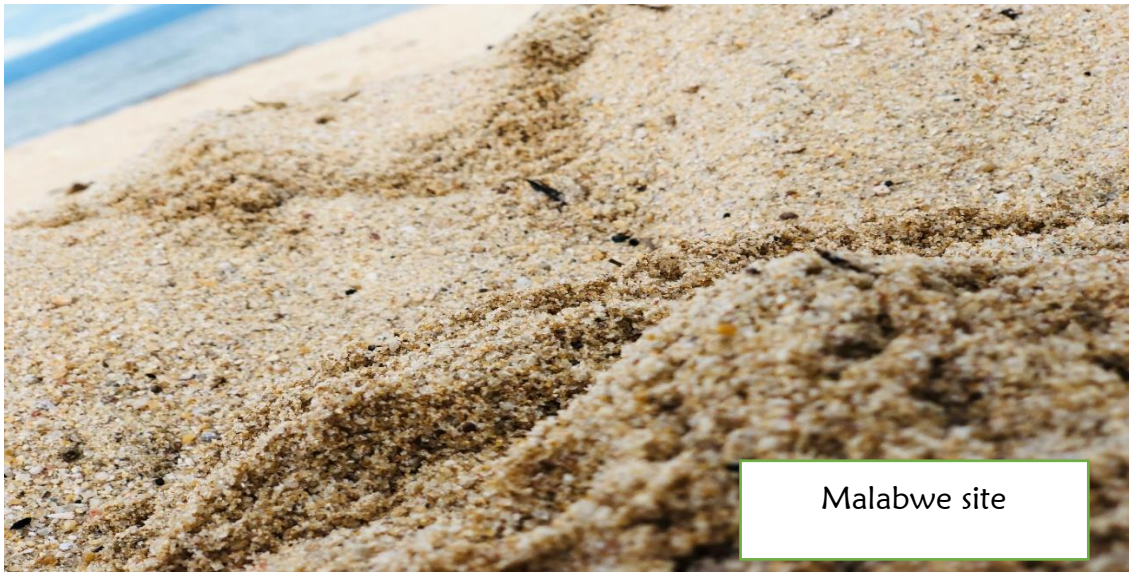
Appendix 1 : Sample Collection sites and data recording



Masasa 1 site



Masasa 2 site



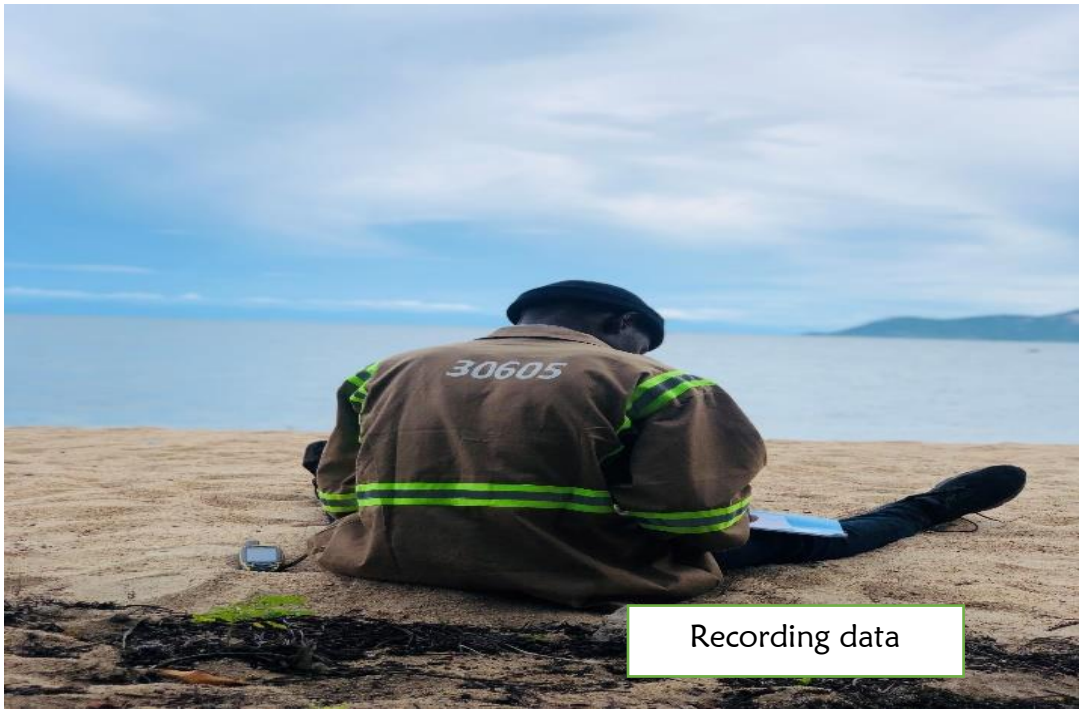


Figure 12 Showing Sample Locations and data recording

Appendix 2: Laboratory sieve analysis



Figure 13 showing sieve analysis process

Appendix 3: Laboratory testing for organic Impurities:

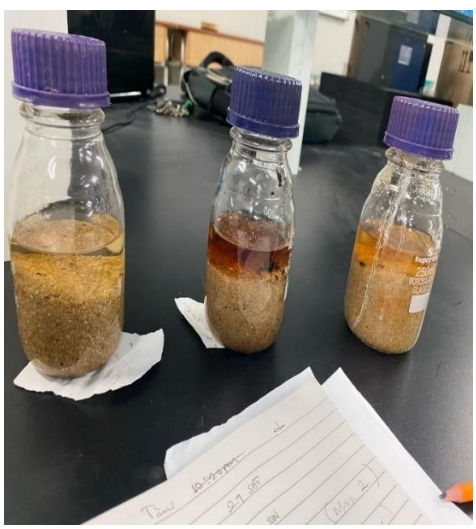




Figure 14 Showing Organic Impurity Results

Appendix 4: Tables of results for grain size analysis

SIEVE SIZES (mm)	ASTM C33 FINE LIMIT	ASTM C33 COASER LIMIT	MATERIAL RETURNED (g)	%MATERIALS RETURNED	CUMULATIVE % RETURNED	CUMULATIVE % PASSING
4.74	95	100	0	0	0	100
2	80	100	9.6	0.96	0.96	99.04
1	50	85	32.1	3.21	4.17	95.83
0.425	25	60	821.3	82.13	86.3	13.7
0.25	5	30	125.5	12.55	98.85	1.15
0.106	0	10	11.1	1.1	99.95	0.65
		TOTAL	999.6	TOTAL	290.23	

Table 4 Showing Grain Size results for Masasa 1

SIEVE SIZES (mm)	ASTM C33 FINE LIMIT	ASTM C33 COASER LIMIT	MATERIAL RETURNED (g)	%MATERIALS RETURNED	CUMULATIVE % RETURNED	CUMULATIVE % PASSING
4.74	95	100	0	0	0	100
2	80	100	10.2	1.02	1.02	98.98
1	50	85	286.6	28.66	29.68	70.32
0.425	25	60	687.3	68.73	98.41	1.59
0.25	5	30	14.8	1.48	99.89	0.11
0.106	0	10	0.5	0.05	99.94	0.06
		TOTAL	999.4	TOTAL	328.94	

Table 5 Showing Grain Size Results for Masasa 2

SIEVE SIZES (mm)	ASTM C33 FINE LIMIT	ASTM C33 COASER LIMIT	MATERIAL RETURNED (g)	%MATERIALS RETURNED	CUMULATIVE % RETURNED	CUMULATIVE % PASSING
4.74	95	100	0	0	0	100
2	80	100	6.7	0.67	0.67	99.33
1	50	85	177.6	17.76	18.43	81.57
0.425	25	60	740.8	74.08	92.51	7.49
0.25	5	30	56.9	5.69	98.2	1.8
0.106	0	10	1.7	0.17	98.37	1.68
		TOTAL	983.7	TOTAL	308.18	

Table 6 Showing Grain size Results for Malabwe