

**The Study of Collapsible Soil Mixed with Marble Dust: In Case of
Adama - Awash Road Project**



By:

Mihiret Rebo Geda

**A Thesis Submitted to the Department of Civil Engineering,
School of Civil Engineering and Architecture**

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**Office of Graduate Studies
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**September 2023
Adama, Ethiopia**

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Adama Ethiopia

DECLARATION

I declare that this thesis entitled “The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project” is my work and has not been submitted to any university for a similar purpose. The references used in this Thesis are duly recognized by proper citations.

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APPROVAL PAGE

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ABBREVIATION

AASHTO.....	American Association and Transportation of State Highway Officials
ASTM.....	American Society for Testing of Materials
CBR.....	California Bearing Ratio
CI.....	Collapse Index
CP.....	Collapse Potential
ERA.....	Ethiopians Roads Authority
GPS.....	Global Positioning System
HEIC.....	High Energy Impact Compaction
LL.....	Liquid Limit
MDD.....	Maximum Dry Density
NMC.....	Natural Moisture Content
NP.....	Non Plastic
OMC.....	Optimum Moisture Content
PI.....	Plasticity Index
PL.....	Plastic Limit
RIC.....	Rapid Impact Compaction
USCS.....	Unified Soil Classification System

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ABSTRACT

Collapsible soils present major obstacles in construction and infrastructure projects due to their tendency to shrink when wet, resulting in structural instability and settlement problems. This research investigates the use of marble-based treatment to combat collapsible soils, a common problem in construction and infrastructure development. By varying the percentage of marble content in the soil (ranging from 0% to 50%), the study examines its impact on critical soil properties and collapsibility. The results show that increasing marble content improves soil compaction, reduces water requirements for compaction, and decreases soil plasticity. The maximum dry density steadily rises, indicating improved soil compaction. Simultaneously, the optimum moisture content decreases, reducing the amount of water needed for compaction. Additionally, the liquid limit, plastic limit, and plastic index values all show a favorable trend, indicating a reduction in soil plasticity. Furthermore, the California Bearing Ratio (CBR) values exhibit significant improvement with higher marble content, signifying an increase in the soil's load-bearing capacity. The swelling index decreases, reflecting reduced soil expansiveness as the marble content increases. However, it's worth noting that cohesion values decrease with higher marble content, while the angle of internal friction increases, indicating changes in the soil's shear behavior. The Collapsible Index, which measures how likely the soil is to collapse after being wet, significantly decreases with marble concentration, with numerical values falling from 9.08 at 0% to 1.2 at 50%. CBR values also rise from 22 to 31.5 at the same time. Further demonstrating improved soil shear behavior are direct shear measurements that show better cohesiveness and angle of internal friction values with higher marble concentration. These results highlight the marble-based treatment's potential to considerably reduce soil collapsibility. The Collapsible Index and CBR values' numerical representations vividly show the significant advancements made, highlighting the research's application to soil stabilization and infrastructure construction. With the potential for widespread application in areas afflicted by collapsible soils, this study offers insightful information for geotechnical engineering practices. It is advised to conduct more studies and field testing to examine the long-term performance and environmental effects of marble-based soil treatment.

Keywords: Soil Stabilization; Waste Marble Dust; Collapsible Soils

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1. INTRODUCTION

1.1 Background

Moisture-sensitive soils that collapse when wet are called collapsible soils because they do so significantly less of their original volume. These soils usually consist of silts and fine sands. Although these soils are present throughout the planet, they are usually found in dry and semi-dry regions. (Al-rawas, 2000) Particularly when carrying an additional load, saturation in the collapsible soils causes a rapid decrease in volume. Such events cause the soil to deform severely, damaging the structures. (Haeri, 2016). Structures built on soils that are prone to or capable of collapsing are vulnerable to damage. Volcanic tuff, residual soils, loess deposits, aeolian deposits, alluvial deposits, colluvium deposits, and alluvial soils are among the soil types that might collapse. (Howayek et al., 2015)

Collapsible soil, often known as "loess," poses a puzzling challenge to engineers and building experts everywhere because of its unique behavior under various moisture circumstances. When subjected to water infiltration, this type of soil has a large loss in volume and bearing capacity, which causes settlements, fractures, and structural instability. This phenomenon could have negative effects on construction and infrastructure projects that are near or on collapsible soil deposits. Collapsible soil difficulties require innovative and long-lasting remedies if developed structures are to remain sturdy and long-lasting. Collapsible soils, also known as loess soils in certain literature, are porous, low-density soils that are prone to considerable deformations when wet, despite having a relatively high apparent strength when dry. (Opukumo et al., 2022)

Soils that can collapse are those that can break under significant volumetric loads. Several different soil types are included in the general category of collapsible soils, including loess, a well-known Aeolian deposit ubiquitous across most of the earth. Loess has a decent degree of strength and stiffness when dry, but because of its low density and cohesion when wet, it is vulnerable to significant deformations. The wetting-induced collapse in loess-type soils has been seen in both naturally occurring deposits and manufactured fillings. They usually lead to large differential settlements in the latter case, which reduce the structure's usable space and raise the frequency and

cost of restoration. These issues are especially troubling given the nation's developing infrastructure.

Collapsible soils in Ethiopia, in contrast to numerous additional forms of troublesome soils, have not gotten the necessary attention in research conducted to understand. But because of their unique technical features, they demonstrate significant settlement after soaking, endangering the stability of foundations and embankments that have been built over them. Many specialists in the building industry struggle to understand the features of collapsible soils and how to improve their behavior because there hasn't been much research done on the subject and the country's engineering design guidelines haven't paid much consideration.

Soils that offer major risks to engineering buildings erected on them are referred to as problematic soils. Problematic soils include those that collapse easily, disperse widely, etc. One class of problematic soil is collapsible, which is defined as having a considerable, abrupt, and irreversible volume loss upon wetness. With some clayey particles and rock pieces, these soils primarily consist of sand and silt. (ERA Democratic et al., 2013)

There are numerous techniques for treating and/or enhancing collapsible soils. These techniques include removing the existing material and replacing it entirely or partially, excavating and re-compacting the soil, and the region with cementitious materials, chemical grouting, prewetting and surcharging, impact compaction, dynamic compaction, etc.

Although collapsible soils have been extensively studied in other nations like the United States of America, China, Nigeria, South Africa, etc., there has been little satisfactory research on collapsible soils found in our nation. Collapsible soils have been emphasized in many of the research's current priority areas along with any other problematic soils, but their actual existence has received less attention. Even seasoned engineering professionals lack an in-depth understanding of collapsible soil identification, categorization, and treatment techniques due to the aforementioned factors.

The purpose of this study was to advance our understanding of the collapsible soil enhancement process using waste marble dust. Soil samples were collected from the Adama-Awash Road Project, and laboratory tests such as index property, compaction, CBR, shear strength, and

Collapse Potential tests were conducted on natural soil and improved soil with varying percentages of waste marble dust content. This study contributes to the field of geotechnical engineering while promoting sustainable practices in construction and infrastructure development.

1.2 Statement of the problem

Construction on Collapsible Soils has made problems for geotechnical and structural engineering challenges all over the world. Such as highways, railways, embankments, and foundations constructions. Collapsible soil presents a significant geotechnical challenge in construction projects, characterized by sudden and significant volume changes upon wetting. The conventional methods of stabilizing such soils often involve the use of cementitious materials or mechanical compaction, which can be resource-intensive and environmentally unsustainable. Additionally, the disposal of waste materials like marble dust contributes to environmental concerns. Thus, there is a pressing need to explore alternative, sustainable methods of stabilizing collapsible soil while simultaneously addressing the issue of waste materials.

This study intends to explore the possibilities of using discarded marble dust as a stabilizing agent for collapsible soil in light of these difficulties. This study's main issue is whether waste marble dust, a byproduct of the marble industry, may effectively reduce soil collapsibility while promoting environmentally friendly building techniques. This investigation covers issues such as the chemical and mechanical characteristics of waste marble dust, how it affects soil stability, and whether using this waste material might be advantageous for the environment. By tackling this issue, the study hopes to further the creation of more eco-friendly and efficient techniques for stabilizing collapsible soil, in line with sustainable building objectives and waste reduction principles. Even though just a few texts acknowledge their existence in Ethiopia, a thorough identification and adequate investigation have not been conducted. Even the local instructions only mention the identification of collapsible soils and a few of their characteristics rather than offering precise, acceptable repair methods. As a result, it is discovered that industry professionals lack both knowledge and experience. Cause of this, extensive and ongoing research must be done in construction areas covered by collapsible soils to ascertain the characteristics and improve mechanical properties of the same, develop suitable corrective measures, and address the awareness issue found among construction professionals.

1.3 Research Questions

These research questions address various aspects of the study, including the technical properties of waste marble dust, its impact on soil behavior, environmental considerations, economic feasibility, and implications for sustainable construction practices.

- ✓ How does waste marble dust affect the compaction characteristics of collapsible soil, including optimal moisture content and maximum dry density?
- ✓ What is the impact of waste marble dust on the shear strength properties of collapsible soil, particularly regarding improvements in cohesion and friction angle?
- ✓ Can waste marble dust effectively reduce the collapsibility of soil, leading to enhanced volume stability and load-bearing capacity?
- ✓ What are the potential implications of waste marble dust utilization for other soil types, and what are the recommendations for further research in terms of mixing ratios, long-term performance, and compatibility with different contexts?

1.4 Objective

1.4.1 General Objective

The main objective this study is to investigate the collapsible soil mixed with waste marble dust

1.4.2 Specific Objective

The specific objectives of this study are to:

- Characterize the basic properties of collapsible soil.
- Evaluate waste marble dust properties.
- Assess soil-waste marble dust interactions.
- Perform laboratory experiments and analyze geotechnical properties.

1.5 Significance of the Study

The importance of this study rests in its potential to provide a variety of advantages:

- **Soil Stabilization:** By exploring waste marble dust as a stabilizing agent, the study aims to contribute to an effective and environmentally friendly approach to mitigating the negative

effects of collapsible soil. The potential of waste marble dust to bind soil particles and alter their behavior could lead to increased soil strength and reduced collapsibility.

- **Waste Material Utilization:** Waste marble dust, which often poses disposal challenges, could find a new purpose as a soil stabilizer, thereby reducing its environmental impact and contributing to a circular economy.
- **Sustainability:** By offering a sustainable alternative to traditional soil stabilization methods, the research aligns with global efforts to reduce the carbon footprint and environmental impact of construction practices.
- **Economic Implications:** If successful, the utilization of waste marble dust in soil stabilization could have economic benefits by potentially reducing the cost of stabilizing soil and minimizing the need for expensive additives.

Overall, this research paper aims to bridge the gap between waste material management and geotechnical engineering, demonstrating how waste marble dust can be harnessed to address soil instability issues while promoting sustainable construction and infrastructure development practices.

1.6 Scope of the Study

The scope of this study focused on the investigation of waste marble dust as a potential stabilizing agent for collapsible soil to enhance its engineering properties and mitigate collapsibility.

The laboratory experimental program was carried out for collapsible soil alone, collapsible soil mixed with waste marble dust in different percentages, determined percentage of collapsible soil mixed with optimum waste marble dust, and finally, the treated and untreated collapsible soil was exposed to check the physical and mechanical properties. From Five test pits at 1.5m depth the index and engineering properties of soil examined by the following tests: - Collapse Potential Test, Sieve analysis, Moisture content, Atterberg limits, specific gravity, swell, compaction, CBR, and Direct Shear test. The stabilization of soil was carried out for only one test pit that had the poorest quality, which had the maximum Collapse Potential Index value.

The scope of this research is centered on collapsible soil found in the Adama-Awash Road Project and aims to contribute to sustainable soil stabilization practices.

Finally, the findings of the analysis and comparison research between the characteristics of soil under natural conditions and the properties of soil after adding stabilizing elements are organized and presented.

1.7 Limitation of the Research Paper

Due to time, laboratory equipment, and budget constraints, only some laboratory tests were conducted, like index properties, compaction, CBR, and Shear Strength on collapsible soil with and without waste marble dust figured out in the lab. It would be necessary to undertake additional laboratory and field testing on collapsible soil.

1.8 Organization of the Research Paper

This research is organized into five chapters, containing preliminary to detailed information about collapsible soil properties, identification, and improvement methods. The research work was laboratory based and the thesis organization is as follows:

The introduction of the study includes background, statement of the problem, objectives, scope, and significance of the thesis are all briefly defined in the first chapter. The second chapter of this research summarizes the literature reviews on the existing body of knowledge on collapsible soil behavior, conventional stabilization techniques, waste marble dust properties, and related environmental considerations. The third chapter outlines the materials and methods employed in the study. It includes details such as a description of the study area, sample collection, sample preparation, and the experimental setup. The various laboratory tests conducted, such as compaction tests, consolidation tests, shear strength tests, and collapsibility tests, are explained in detail. Chapter four covers the analysis of laboratory test results and discussions of basic test results obtained from laboratory experiments and geotechnical analyses are presented and discussed. The final chapter of the thesis presents the conclusions and recommendations with the proposed area for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Metastable, unsaturated soils with a porous structure are referred to as collapsible soils. They frequently take the shape of deposits. Due to the natural cementation between the grains, this type of soil can resist large loads when it is dry. However, even in the absence of additional stresses, saturation causes the intergranular bonds to fail, giving rise to a denser structure and the collapse of the soil particles. These metastable soils often have a small number of fine components and a predominant percentage of silts. (Opukumo et al., 2022)

These soils primarily consist of silt, with trace amounts of sand and clay. The most typical kind of windblown soil is loess. Loess has an open (honeycomb) structure with a very high void ratio caused by the deposition mechanism. Because it serves as a binder to hold the structure together (together with calcium carbonate), the loess' clay component is crucial. However, the soil experiences shear failures and/or settlements when it is moist causing the calcium carbonate bonds to break down or the negative pore pressures in the clay to decrease. These soils seem sturdy and stable in their natural state (dry), yet they quickly consolidate when wet, resulting in significant and frequently unexpected settlements. High porosity (greater than 40%) is one of the primary characteristics of collapsible soils. (ERA 2013, *Site Investigation Manual* 2013)

Collapsible soil exhibits a peculiar behavior that causes large volume fluctuations and settlements in response to moisture. Due to the fine-grained particles' loose organization and propensity to quick structural collapse when exposed to water infiltration, silt, and clay are frequently used to describe this distinctive trait. When moisture is added to these soils through rainfall or irrigation, their air-filled gaps become saturated, but in dry conditions, they stay relatively stable. The saturation brings the particles closer together, which abruptly reduces the volume and strength of the soil. Structures constructed on collapsible soil may consequently undergo subsidence and structural instability, providing difficulties for building initiatives. Implementing efficient soil stabilization techniques and technical practices to offset the effects of collapsible soil requires understanding its features. (Ayeldeen et al., 2017)

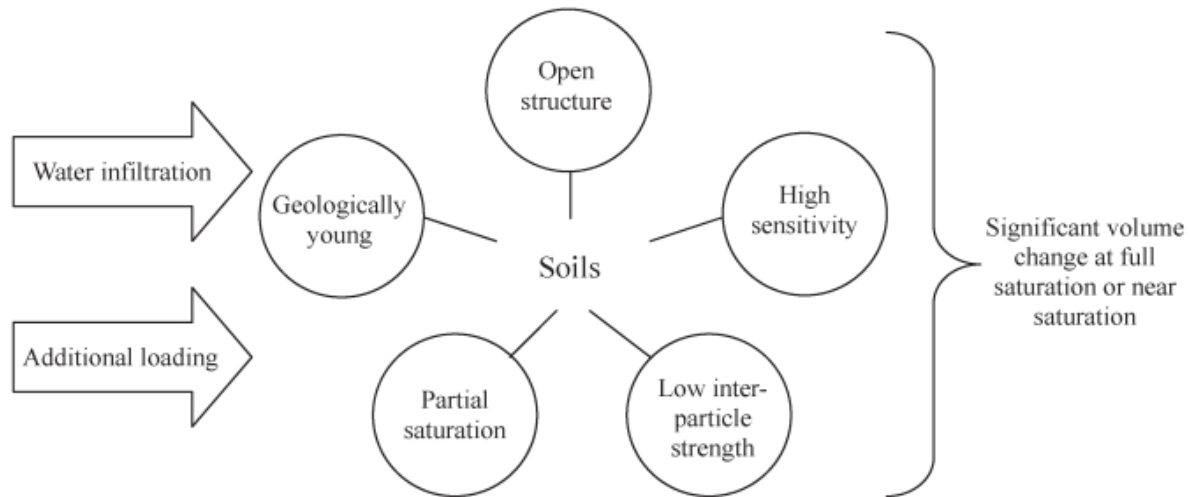


Figure 2.1 Schematic view of key characteristics of collapsible soil (Roger, 1994)

Over the past 70 years, collapsible soils have been extensively studied, producing a large body of literature. These soils, as their name suggests, can alter significantly in volume when wet, with or without additional loads, which presents substantial difficulties for the geotechnical profession. (Howayek et al., 2015) provided a compilation of the major characteristics of collapsible soils:

According to the characteristics of collapsible soils that have been described in the literature, collapsible soils are soils that can experience a significant volume change due to water infiltration alone or in combination with external loading (including self-weight) and dynamic force at full saturation or close to saturation. However, in unsaturated environments, they continue to exist in a stable state. However, generally speaking, the study of collapsible soils is limited to collapse brought on by static external loads, whereas liquefaction processes are usually utilized to study collapse brought on by dynamic forces. In addition to the basic criteria given above, collapsible soils additionally exhibit an open (metastable) structure that results in low bulk density and a high void ratio. (Howayek et al., 2015)

2.2 Classification of Collapsible Soil

Numerous soil types, including compacted soils and naturally occurring soils like aeolian deposits, alluvial deposits, colluvial deposits, residual deposits, and volcanic tuff, can be classified as collapsible soils in general as shown in Figure 2.2.

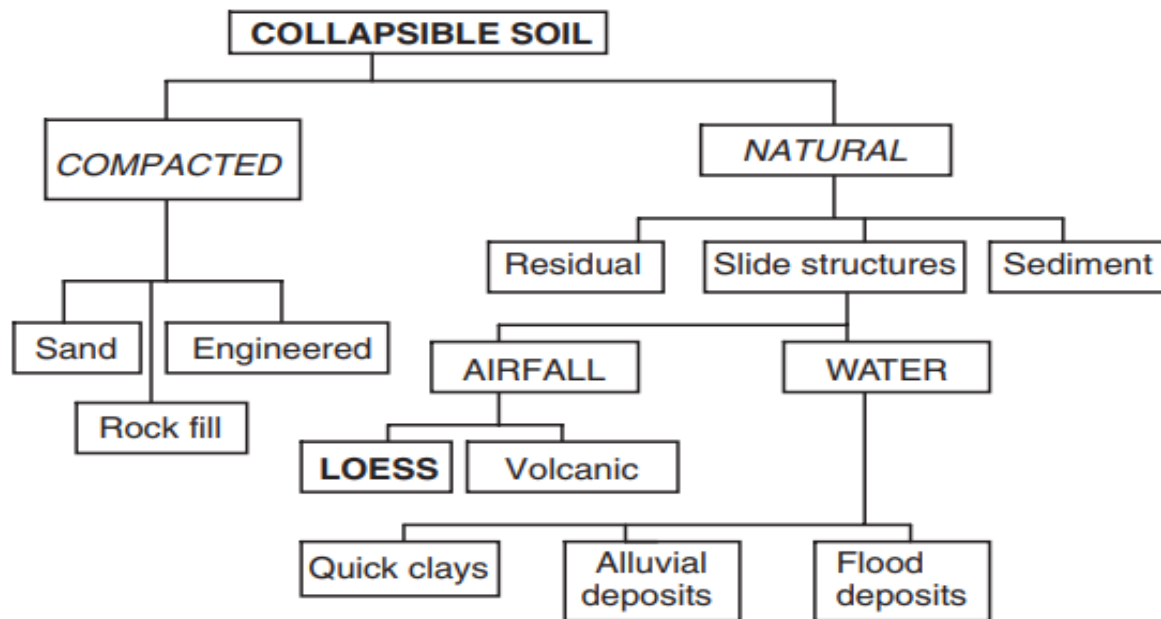


Figure 2.2 Collapsible Soil Classification (Rogers & Member, 1995)

A well-known Aeolian deposit that frequently displays collapsing behavior is loess, a yellow to reddish brown silt-sized soil that has a low density and cohesiveness but noticeable strength and stiffness when dry. In arid areas with low water tables, aeolian deposits with a significant tendency to collapse are frequently encountered. Fine aeolian deposits, however, can still have a high collapsible potential in settings with modest rainfall, like the Midwestern United States. (Clemence and Finbarr 1981), particularly if an impermeable surface crust has protected them from water infiltration.

2.3 Formation of Collapsible Soil

Das stated that wind-deposited sand and/or silts, such as loess, eolic ashes, and volcanic dust deposits, make up the majority of naturally collapsible soils. These deposits are cohesion less or just mildly cohesive and have significant void ratios, generally low unit weights, and low natural moisture levels. Collapsible soils may have cohesiveness cause silt is held in a relatively stable form when it is unsaturated by clay coatings that surround it. The existence of chemical precipitates that have been leached by rainwater may also contribute to the cohesiveness. (Das, 1983).

A collapsing soil structure is made up of loosely packed soil grains that are held in place by cementing substances, capillary tension, and clay bridges. When the aforementioned elements are

diminished or destroyed by wetness and/or surcharge loads, collapse takes place. A significant reorientation of the soil grains during soil collapse causes a change in the soil fabric and a decrease in the soil's porosity. Large volumes of water may have a variety of effects on arid climate soils, including expansion of clays, a decrease in shear strength, changes to the soil-water system, and the disappearance of capillary forces between grains. Therefore, a significant increase in soil moisture may frequently have the effect of altering the soil structure. A surcharge load or other applied boundary pressures

According to the aforementioned claims, collapsing soil is understood to be soil that swiftly experiences a notable loss of volume as a result of a significant reorganization of the soil fabric upon precipitation or the application of a boundary force. Collapse may or may not be induced by a boundary force. (F.J, 1968)

According to Houston, the arid climate, where potential evaporation substantially outweighs rainfall, is to blame for the development of collapsible soils. Capillary tension forces the remaining water to withdraw into the small gaps along the soil grain interface as the near-surface water starts to dry, carrying with it soluble salts, clay colloids, and silt particles. The salt, clay, and silt particles emerge from the solution as the soil continues to dry, tack-welding the huge soil grains at their interface. (S.L.Houston, 2002.)

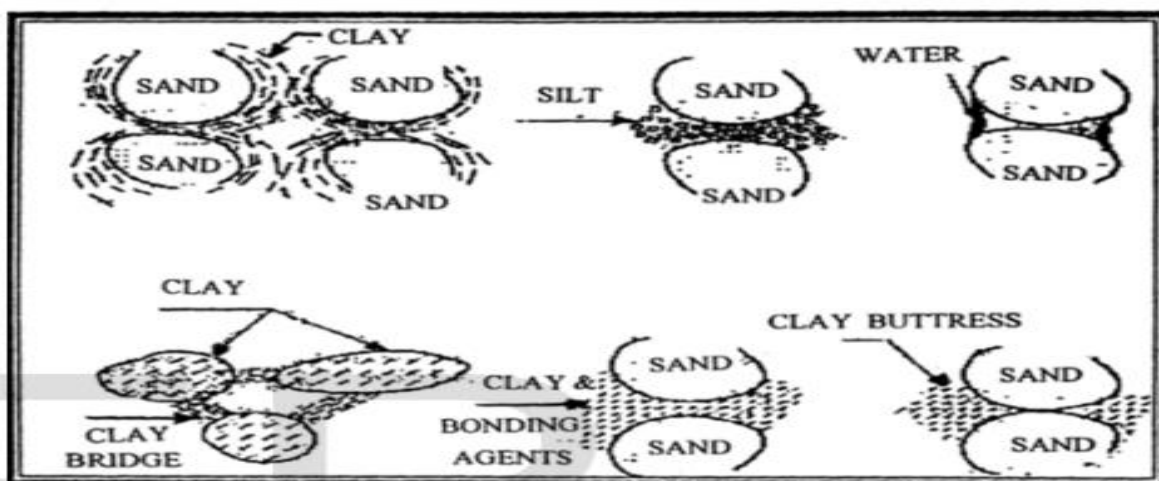


Figure 2.3: illustrates the main forms of collapsible soil structure (After the Egyptian Code of Practice, 2001)

Collapsible soil is characterized by its sensitivity to abrupt volumetric changes when exposed to

water infiltration and is often made up of fine-grained particles, such as silt and clay. Cementing agents like carbonates, which are sensitive to moisture content, are thought to be the main cause of the collapse phenomenon. These cementing substances connect soil particles when the soil is dry, resulting in a relatively stable structure. However, when wet, these linkages deteriorate, resulting in a swift loss of cohesion and a significant decrease in volume and load-bearing capability. (Saygili, 2016)

Collapsible soils are classified as soils with a variety of bonding processes that first arrange the main structural units in an open metastable packing. The soil collapses if the load is greater than the bonding material's yield strength; this rearranges the particles into a denser, more stable structure (see Figure 2.3). As a result, both micro- and macro-level factors can influence the collapse itself. Understanding the underlying nature of collapse and, consequently, how to effectively remedy it, requires an appreciation of both of these factors. (Jefferson & Rogers, 2012)

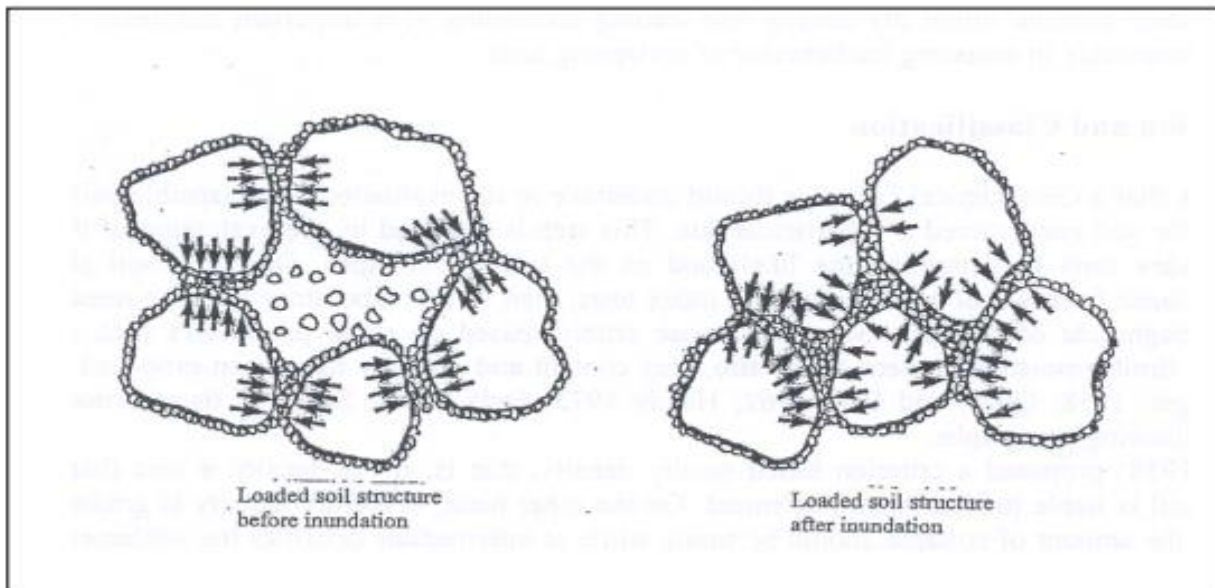


Figure 2.4 Loaded Structure fore and After Inundation (after Casegrade 1993)

Increased stress (load) and the addition of water, which increases saturation levels, are two factors that frequently cause collapse. The most frequent cause of collapse, though, is an increase in water content. Numerous water infiltration points, many of which are found in metropolitan settings, have the potential to cause collapse. Landscape irrigation, broken water or sewer pipes, runoff or inadequate drainage management, groundwater recharge, or changes in water content due to

capillary rise are a few examples. (Jefferson & Rogers, 2012)

A collapsing soil structure is made up of loosely packed soil grains that are held in place by cementing substances, capillary tension, and clay bridges. When the aforementioned elements are diminished or destroyed by wetness and/or surcharge loads, collapse takes place. A significant reorientation of the soil grains during soil collapse causes a change in the soil fabric and a decrease in the soil's porosity. Collapsible soil, commonly referred to as collapsible clay or collapsible loess, is a category of soil that exhibits large volume fluctuations and settlements after being wet. The fast and significant decrease in soil strength and volume that characterizes this behavior could cause structural instability and harm to infrastructure, including foundations and buildings. Collapsible soils are vulnerable to significant subsidence and settlement. (Shah, 2010)

2.4 Collapsible Soil Occurrence and Damage

Collapse occurs because the soil has specific inherent properties. Typical features that are found in most collapsible soils include:

- ✓ An open metastable structure
- ✓ High voids ratio and low dry density;
- ✓ High porosity;
- ✓ Geologically young or recently altered deposit
- ✓ Deposit of high sensitivity;
- ✓ Soil with inherent low inter particle bond strength.

As a result, many soils eventually displayed collapsible behavior. Figure 2.2 shows this together with the many soil development processes that can result in collapsible soil. Over 10% of the earth's surface is naturally covered in collapsible soils. Engineers must identify and control collapsibility before construction because this is seen as a global concern. (Nazir et al., 2020). Similar to what Rort D. Evans et al. reported, windblown silt depositions have created significant surface formations of collapsible soil in North and South America, Europe, Central Asia, and China, including an almost continuous deposit from North China to southeast England. These formations are frequently near densely populated areas and significant infrastructure projects. They can be found in Ethiopia along the southern banks of the Omo River and in the southern rift valley of the central plain. They frequently show themselves in the form of ground cracks and

potholes following severe rains or floods due to hydro-compaction in the areas of Hawassa, Shashemene, Zeway, Adama, and Metahara. The region of Afar contains dunes made of collapsible earth. (ERA 2013, *Site Investigation Manual* 2013)

Collapse and other collapse-related issues, including differential settlement, earth cracks, landslides, and falls, have caused major harm to infrastructure built on loess soils and in some cases even resulted in fatalities. In China, it was stated that between 1974 and 1975, the collapse of loess soils caused a total of 1505 buildings to be damaged as well as an 80 km-long subterranean pipeline to burst. (Li et al., 2016)

A commercial structure in New Mexico served as an illustration of the effects of urbanization and related landscaping. The structure sustained US\$ 500,000 in foundation damage as a result of soil collapse after receiving the city's most beautiful grass and landscaping award through intensive watering. (Houston *et al.*, 2001). Water penetration causes a somewhat abrupt volume compression that is frequently accompanied by strength loss. This may have significant geotechnical repercussions, such as loss of serviceability necessitating pricey rehabilitation or, occasionally, total failure. The structural disasters brought on by damaged foundations on collapsible soils in Egypt served as an example of this. (Sakr *et al.*, 2008), The issues with dam collapse brought on the hydrogeological changes related to dam development in Brazil (Vilar and Rodrigues, 2011).

2.5 Identification of Collapsible Soil

For construction projects to be completed successfully in places where soil collapsibility is a concern, identifying collapsible soil is an essential stage in geotechnical evaluations. Collapsible soil can be recognized using several important signs. Fine-grained particles, especially silt and clay, which serve as the foundation of collapsible soils, are one of their fundamental characteristics. During dry seasons, field investigations frequently show surface fissures or cracks, showing the soil's inclination to shrink upon water loss. The particle size distribution of the soil can quantitatively be assessed by laboratory procedures like the double hydrometer test, which can also assist in distinguishing between collapsible and non-collapsible soils. Similar to the slake durability test, water infiltration tests replicate wet circumstances and determine how susceptible the soil is to structural disintegration under saturating conditions. Additionally, the characteristics of collapsible soils are distinct.

2.5.1 Field Identification

Visual observations combined with quick tests that reveal information about the behavior of the soil when wet is used to identify collapsible soil in the field. One obvious sign is the existence of surface fissures, cracks, or "popcorn-like" textures on the soil's surface during dry periods. These characteristics are unmistakable evidence of soil shrinkage upon water loss, a characteristic of collapsible soils. The soil's friable quality, which causes it to quickly break into loose fragments when touched, is another feature. Field tests, such as the thumb penetration test, entail pressing the soil with the thumb; if the soil easily crumbles into a powder-like texture, collapsibility is likely. Water infiltration tests provide real-time information since they can detect collapsible behavior by causing immediate subsidence or sinking when water is applied to a dry soil surface.

S. L. Houston and colleagues (2002) advise that local site geology and depositional processes should be taken into account for anything else when figuring out the chance that the soil profile may collapse. This data, together with climatological information, can be a highly useful tool for planning the site inquiry. When analyzing an existing roadway, geomorphological clues, and performance data can be used to identify any potentially hazardous soil conditions. There is a direct relationship between geographic and geological information and collapse potential. Engineering knowledge, familiarity with the functioning of the regional infrastructure, and knowledge of the site's geological features are essential components of the site characterization. There is a simple test that can be carried out on-site in addition to forecasting the presence of collapsible soils based on geographic and geological data.

Additionally, according to ERA's Site Investigation Manual, the formation of ground fissures and potholes during severe rains or floods due to hydro-compaction frequently indicates the presence of collapsible soils. (ERA 2013, *Site Investigation Manual 2013*)



Figure 2.5 Collapse holes near Shashemene (source: ERA 2013, Site Investigation Manual)

2.5.2 Laboratory Identification

You could identify collapsible soils by doing several laboratory tests. Direct and indirect techniques as well as mineralogical identification are often categorized as these. Collapsible soils can be found using a variety of methods. Direct methods and indirect methods can be considered as the two main categories. The indirect methods determine the likelihood of collapse by comparing it to other index and mechanical characteristics like unit weight, Atterberg limits, or percentage of clay particles. Even though these classifications are often helpful, they don't offer many quantitative projections of prospective settlements. One such correlation is made by Clevenger (1958) who developed a dry density threshold, meaning that the soil is susceptible to severe settling if the density is low 1.28 g/cc. The quantity of collapse, however, should be minimal if the dry density is higher than 1.44 g/cc, and the settlements at intermediate densities are transitional. (A. A. Al-Rawas, 2000)

The Geotechnical ERA Design Manual, on the other hand, outlines how the soil's ability to collapse typically depends on the soil's density, gradient, initial water content, composition, and level of loading at the moment of wetting. A very low density is a reliable sign of a significant likelihood of collapse. The density of typical collapsible soils is less than 1.6 g/cc, with the majority falling between 1 and 1.585 g/cc. (ERA-2013) However, it should be highlighted that since non-collapsible soils also exhibit a wide range of dry densities, the dry density alone appears to be

deceiving and an unreliable indicator of collapse. Additionally, other factors were not considered, such as the moisture content of the soil, which has a significant impact on soil collapse.

Bell and Bruyn (1997) developed a standard based on the natural dry density and liquid limit that distinguishes between collapsible and non-collapsible soils, as shown in Figure 3. The method is based on the notion that soil, even when it has enough space to keep its liquid limit moisture at saturation, is prone to collapsing when it comes wet. Figure 3 shows that loose soils above the lines, which are marked as possibly metastable, are vulnerable to collapsing when completely saturated with moisture levels higher than the liquid limit.

Bell and Bruyn (1997) reported a criterion suggested by Gibbs and Bara (1962) As illustrated in Figure 2.6, the difference between collapsible and non-collapsible soils is based on natural dry density and liquid limit. The approach is predicated on the idea that soils that have adequate space to contain their liquid limit moisture at saturation are when wet, susceptible to collapse. Figure 2.6 demonstrates that the loose soils above the lines have a moisture content that is higher than the liquid limit when they are fully saturated. Handy (1973) proposed using the liquid limit-to-saturation ratio as a criterion. The soil collapses if this ratio falls below 1. The soil is not collapsible, though, if it is more than 1. Dudley (1970) reported that most of the collapsing soils have liquid limits low 45 % and plasticity indices low 25%

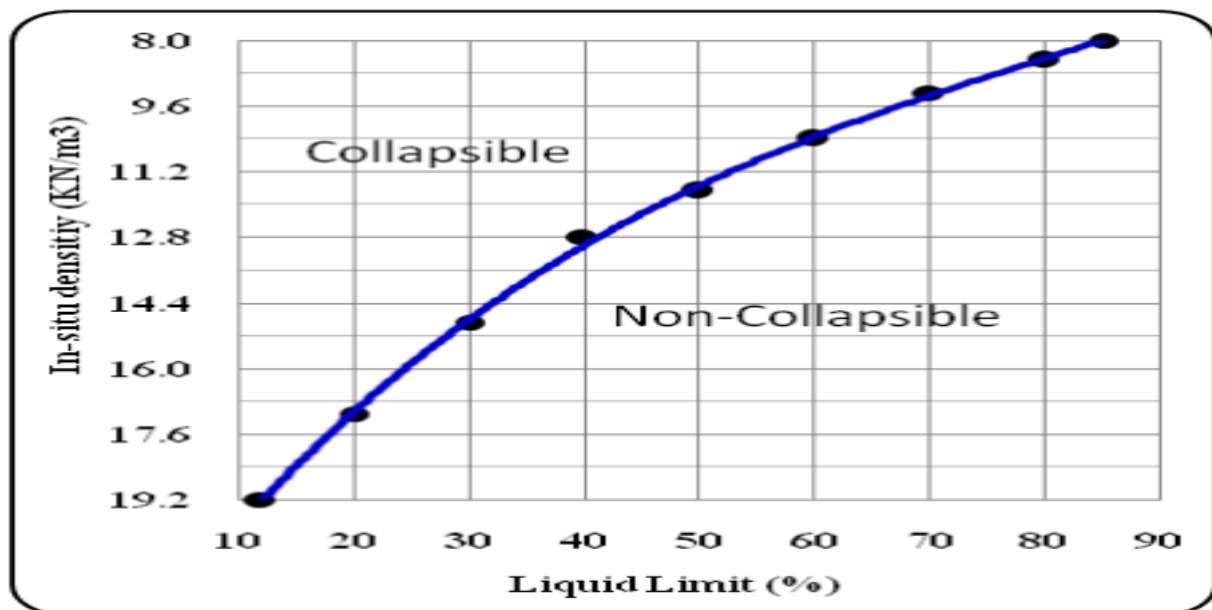


Figure 2.6: Classification of collapsing soils (after Gibbs and Bara 1962)

The use of these criteria alone, however, can be deceptive as they only serve as indicators of the likelihood of soil collapse. Once the soil exhibits signs of the potential for collapse, direct evaluation of the collapse's size is therefore crucial. (A. A. Al-Rawas, 2000) However, direct approaches require soaking the soil, either in a lab or in the field, while also monitoring the related strain. These methods include single and double Oedometer tests as well as various in-situ collapse studies. These tests can predict potential settlements by generalizing results to the entire soil deposit. (Baytar, April, 2005)

ASTM D5333, explains how to determine how much one-dimensional collapse happens when unsaturated soils are flooded with fluid. Collapse Potential (I_c), the percent-relative magnitude of soil collapse calculated at any stress level, and Collapse Index (I_c), the percent-relative magnitude of collapse found at 200 kPa, are its two defined parameters. Equation 1's formula for calculating one parameter can also be applied to the other.

$$I_c = \Delta e_{1+e_0} * 100 \text{ (eq.1)}$$

Where Δe = change in void ratio resulting from wetting e_0 = initial void ratio

Based on the test results, which are reported in Table, ASTM D5333 further details the degree of collapse. Figure 3 illustrates the usual behavior of the one-dimensional collapse potential test graph. The area of the Graph starting with point "A" to point "B" depicts the settlement brought on by load increases up until the proper vertical stress, which is decided by whether the collapse index or potential is to be calculated. The settlement is attributable to collapse only as a result of the specimen being submerged at a consistent, acceptable rate. vertical tension is shown in the section from "B" to "C". The result of this reading being entered into equation 1 is reported as collapse potential/index. The section from "C" to "D" shows the amount that needs to be paid.

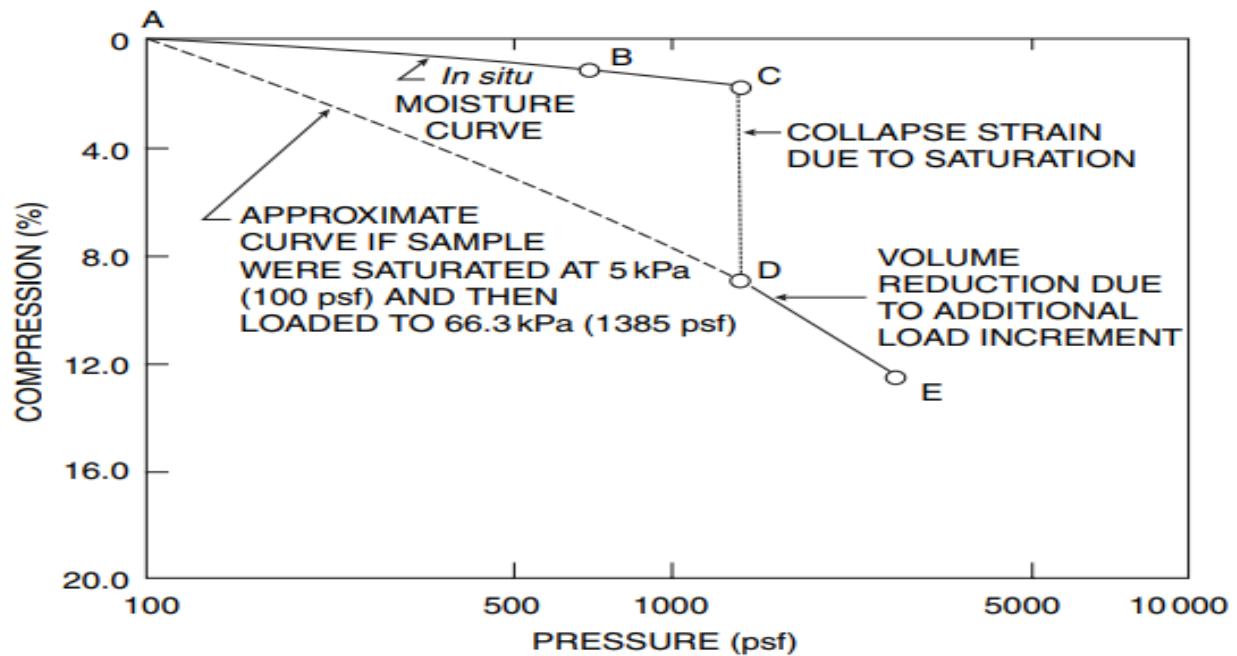


Figure 2.7: After the typical compression curve for collapsing soil Collapsible Potential Test (Source: ASTM D5333)

Table 2.1: Sorting the Collapse Index as per ASTM D5333

Degree of Collapse	Collapse Index (%)
None	0
Slight	0.1-2.0
Moderate	2.1-6.0
Moderately Severe	6.1-10.0
Severe	> 10.0

2.5.3 Mineralogical Identification

The potential for clay soil swelling in collapsible soils is significantly influenced by their mineralogical makeup. The mineralogical makeup of clay soils can be ascertained using the following techniques.

- ✓ X-ray diffraction,

- ✓ Differential thermal analysis,
- ✓ dye absorption,
- ✓ chemical analysis
- ✓ Electron microscope resolution

These methods take a lot of time, need pricey test equipment, and require skilled people to analyze the results. Therefore, these methods are rarely used in routine engineering work.

2.6 Treatment of Collapsible Soil

In challenging ground conditions, numerous research studies on ground improvement strategies are advised. Examples include swelling soils, collapsible soils, soft soils, and organic soils. Any of the following alternative solutions may be used when a project site encounters one or more of the aforementioned challenging conditions, depending on the site in question: designing the intended structure, removing and replacing unsuitable soils, attempting to Use soil enhancement techniques, construction projects can avoid changing the existing ground, enable cost-effective foundation design, reduce the consequences of contaminated soils, and ensure sustainability. The carrying capacity and settling of shallow foundations can be increased and reduced using a variety of soil improvement approaches. These methods include stone columns, soil replenishment, prewetting, dynamic compaction, and chemical stabilization as examples.

2.5.1. Prewetting

Prewetting is the process of flooding or watering the soil that is likely to collapse upon saturation before the structure is completed to reduce soil collapse after the structure is erected. Prewetting was discovered to be one of the simplest and least expensive therapies, however, it was useless in lowering the risk of collapse. (Murthy, 2007)

Abdelaziz (2007) also stated that (Rogers & Member, 1995) Researchers examined the prewetting effect and discovered that the ultimate collapse settlement after prewetting was essentially the same as the settlement where no treatment was applied. For prewetting to be effective, preloading, surcharging, and preloading must also be used.

2.5.2. Dynamic Compaction after Prewetting the Soil

By raising the moisture content of the soil for dynamic compaction to boost the compaction

efficiency, wetting, and dynamic compaction can be utilized to regulate or limit the possibility of collapsibility. According to Rogers and Member, 4% of the value in the case of no treatment was the collapse settlement using this method, which examined the effects of prewetting the soil and dynamic compaction on the collapse settlement. The densification throughout the entire area was more uniform than compaction at the natural moisture content. (Rogers & Member, 1995)

Ali developed an investigation of the collapsibility potential's relationship with relative compaction and starting water content. The investigation revealed that decreasing the risk of collapsibility potential requires increasing relative compaction energy and degree of saturation. (Ali, 2015)

2.5.3 Dynamic Compaction of Soil at Natural Moisture Content

Collapsible soil can be wet and re-compacted using heavy rollers or strong tamping. Spread footings and matting may be used to cover the compacted ground. Heavy tamping is mostly accomplished by repeatedly dropping a heavy weight onto the ground. The height of the drop can vary from 8 to 30 meters. The stress waves brought on by weight loss contribute to the densification of the soil. (Das, 1983) Rogers and Member conducted in situ tests using this method where a concrete block was used with a specified weight and was dropped from a specified height using a crane. (Rogers & Member, 1995) This method's result showed that the final collapse settlement was only around 1% of what it would have been with no treatment. The classification of natural soil was altered when collapsible soil was compacted to 95% of its dry density, which increased bearing capacity by around 24–30% and decreased collapse potential to about 0.15–0.23. (Gaaver, 2012)

2.5.3.1 High Energy Impact Compaction

High Energy Impact Compaction, also known as rolling dynamic compaction, is a relatively new technology that is gaining popularity due to because of its capacity to compact the ground more thoroughly, i.e., to larger depths than static and vibrating roller counterparts, and more effectively because of its faster speed 12 km/h compared to 4 km/h using typical rollers. It has been successfully used in various implementations around the world with modules that have 3, 4, and 5 sides. (Jaksa et al., 2019) High-impact energy impact compaction ground treatment imparts vertical energy into the ground to depths ranging from 2–5 m. Given the near-vertical energy input, the spread of energy along the ground surface as surface waves is minimized. It is the surface

waves that generally cause the vibration to be transmitted along the ground to adjacent structures (Narendranathan, 2015)

In comparison to conventional static or vibratory rolling, this is normally only applicable to depths of 0.5 meters, HEIC has shown compaction effort to more than one meter (and more than 3 m in some soils) below the ground surface. This is a result of the module's mass, which is quite high, along with its kinetic and potential energies. Furthermore, HEIC is exceptional in that it can compact sizable open regions at depth productively and effectively. (Jaksa et al., 2019)



Figure 2.8-Three-Sided Impact Rollers (Jaksa et al., 2019)

Several projects with subgrades at risk of collapsing have used the high energy impact compaction technology M. I., Pinard, and S. Ookeditse (1988) a 215 km long road building project has tested impact compaction Serowe-Orapa found 300 km north of Gaborone, Botswana, analyzing the impact compaction roller's performance in improving collapsible soils and deciding whether it is more practical and cost-effective than traditional compaction rollers.

Consolidation tests were performed on undisturbed samples, saturated at pressures of 36 kPa, to determine the sandy subgrade's compressibility properties following various increments of roller passes. (approx. equivalent to the total of overburden, construction, and traffic stresses) and 200 kPa. The accompanying figure illustrates typical test findings, which show that after 30 and 60 passes with the impact roller, respectively, the sand's collapse potential dramatically decreased from its fore compaction values of approximately 11% to about 3.7% and 2.0%. (Narendranathan, 2015)

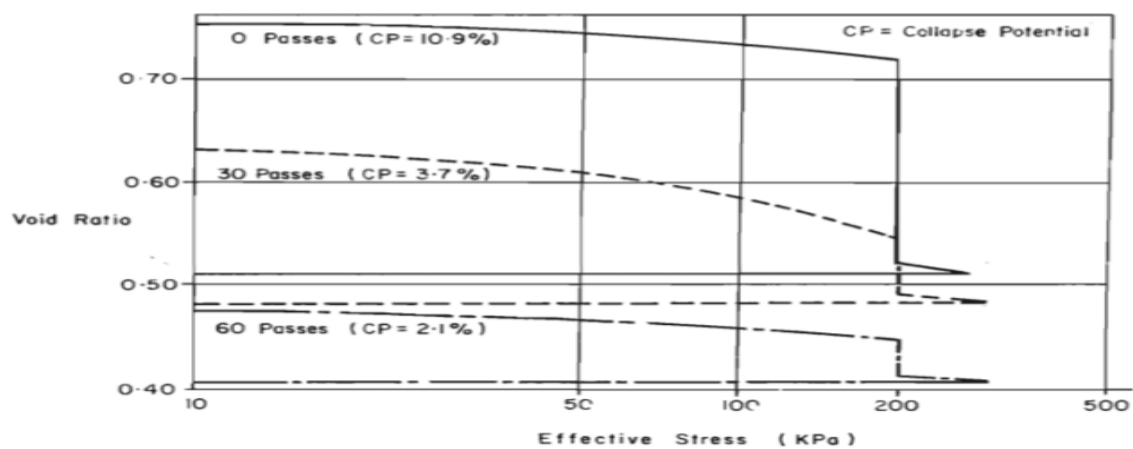


Figure 2.9: Collapse Potential vs. Number of Passes (Narendranathan, 2015)

2.5.3.2 Rapid Impact Compaction

To enhance the Deep Dynamic Compaction method, British Sheet Piling created Rapid Impact Compaction in the early 1990s in collaboration with the British Army. RIC is quick, economical, and capable of reaching difficult sites. (Mohammed, Majed & Hashim, Roslan & Salman, A. (2010)

The rapid-impact compactor (RIC), which is often mounted to tracked base excavators weighing 35 to 70 tons, provides the benefits of improved accessibility and mobility combined. Dynamic energy is added by hydraulically lowering the weight from a controlled height onto a circular or 1 or 1.5 m² footplate. The RIC uses a 5-, 7-, 9-, or 12-ton drop weight to strike the soil at a pace of 10 to 60 blows per minute. There is a drop height variation of 1-2 meters. for so long as the RIC's foot is on solid ground, Secure and efficient energy transmission to the ground is achieved. The ejection of no flying debris. An onboard data-gathering system on the RIC allows for autonomous

control and monitoring of the compaction parameters, including energy, blow counts, and soil penetration. An inbuilt computer controls impact set termination criteria and records crucial data for the rapid-impact compactor. Total energy intake, total penetration, and penetration of the final set are the data that are gathered at each impact site. (Becker, 2011)



Figure 2.10: A Typical RIC Unit (Becker, 2011)

2.5.4. Chemical Stabilization

Chemical stabilization is the alteration of soil characteristics to enhance its engineering capabilities. The two most popular chemical stabilization techniques are lime stabilization and cement stabilization. Salt treatments with ammonium sulfates $(\text{NH}_4)_2\text{SO}_4$ and potassium chloride KCL are other chemical additives that can chemically react with the soil. To improve the quality of the stabilized soil, fly ash can also be added to soil cement and soil lime. cause of the decrease in compression brought on by the addition of lime or cement, treated soil has no potential to collapse. It is also feasible to saturate foundation trenches with solutions of calcium chloride and sodium silicate to stabilize the soil chemically. When the ground was fully soaked, it resembled soft sandstone and resisted collapse. (Das, 1983)

2.5.5. Stone Columns

The soils that collapse easily may be densified with vibro flotation. A vibrating apparatus like the one in Figure (2) is used in the procedure. With an eccentric weight within, it can vibrate horizontally. Water jets are also located at the top and bottom of the device. Collapsible soil with minimal particles can be treated with this technique. (Das, 1983)

2.5.6 Soil Replacement

One of the most well-known methods for coping with collapsing soils is soil replacement. The weak soil is removed, and better-compacted dirt is put in its place. Unfortunately, since it is based on experience, the estimation of replacement layer thickness is in doubt. (Varghese, 2012)

Rollins and Rogers reported that this approach has several benefits, including a reduction in the volume of material that can collapse in an area under stress, an increase in the depth at which water must percolate before reaching collapsible material, and a reduction in the induced stress that the collapsible soil is subjected to. This decrease in produced stress may prevent it from rising above the threshold level required to cause severe collapse settling. This method also reduces the differential settlement near the footing. (Rogers & Member, 1995)

Additionally, experiments were done on circular footings lying on soil that could collapse, and water was allowed to seep into the soil from the bottom. A significantly lower collapse settlement, increased bearing capacity, and low, uniform settlement were all achieved by using a cushion of compacted sand twice the diameter of the footing. Within the measured range, it was discovered that the plate width was the most efficient thickness for the compacted sand layer. Ali proved that it is feasible to improve collapsible soils by substituting sand or crushed stone to reduce or manage the risk of abrupt settling when exposed to water. Additionally, she discovered that replacing the soil with compacted, cohesion-free soil reduced foundation settling by around 50% and increased bearing capacity by roughly 100%. For adding the top compacted sand replacement, the subgrade should be improved through compaction and pre-wetting. (Ali, 2015)

2.6 Type of Stabilization Techniques

Numerous techniques can be used to stabilize soil (Makusa, 2012). All of these techniques can be divided into two categories: mechanical stabilization and chemical stabilization. (Tefera A. & Leykun, 1999).

2.6.1 Mechanical Stabilization

Mechanical stabilization, which doesn't use any chemical additives, is an older kind of stabilization. When a soil structure can withstand lateral movement under stress, it is referred to as mechanically stable (Akinmade, 2008). One of the first methods of soil stabilization was mechanical stabilization, which physically modifies the soil mass by compaction, either static or dynamic. Dynamic compaction is the process of packing the ground evenly and non-compressible by repeatedly dropping a large weight onto it at regular intervals (Shimola, 2018). Using silt, clay, coarse aggregate, and fine aggregate in the right proportions and properly compacted, one may create stable soil. Mechanical stabilization is the name given to the process of controlled grading. To achieve mechanical stabilization, soil must be compacted, without the use of chemicals or other materials. The amount of water in the soil remains largely unchanged, but mechanical energy decreases the number of voids. Additionally, it reduces the soil's porosity, permeability, and compressibility while raising the dry density (Akinmade, 2008).

2.6.2 Chemical Stabilization

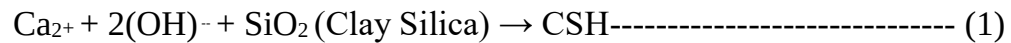
The soil is considered to chemically stabilizing when It is enhanced with organic and inorganic chemical components to enhance its engineering capabilities. To get the desired result, this chemical stabilization technique relies on a chemical interaction tween the stabilizer and soil minerals. (Asres, 2017) The process of chemical stabilization involves mixing pozzolanic and cementitious ingredients, such as lime, cement, fly ash, bagasse ash, calcined termite clay powders, agricultural byproducts, and petroleum byproducts, etc., with weakly resistant soils to increase their stability, toughness, swelling, permeability, and durability. Following are some chemical processes that chemical stabilization can use to enhance soil. (Asres, 2017)

➤ Flocculation and Agglomeration

According to Eden Asres, cation exchange causes a shift in the electrical charge surrounding the clay particles. Consequently, this causes an increased attraction between particles, resulting in flocculation and agglomeration. This results in the decrease of clay-sized particles and thus, the soil surface area, which explains the soil's increased swelling and decreased flexibility. (Asres, 2017)

➤ Pozzolanic Reactions

The stabilization of the soil is greatly aided by time-dependent pozzolanic processes. (Asres, 2017) They are in charge of enhancing different soil qualities. Pozzolanic components can combine to create compounds such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) It could increase the soil's strength.



Clay chunks are initially coated and bound together by the calcium silicate gel that has developed. The gel then solidifies to create a flocculated structure, which strengthens the soil by connecting.

The following are a few chemical additions used to stabilize soil:

➤ Cement stabilization

Cement stabilization is the most common method of stabilization with additives. Soil cement (a mixture of soil and cement) has been used as foundation material in many projects, such as highway pavement, building pads, and slope protection of dams and embankments. Cement stabilization differs from other forms of chemical stabilization in such a way that structural strength is primarily gained from the cementing action rather than from internal friction, cohesion, or chemical ion exchange of the materials. Almost all types of soils can be used for cement stabilization except highly organic soils or heavy clay soils. (Teferra, 1986)

➤ Lime and Fly ash stabilization

Three forms of lime are produced when limestone is broken. These are quick lime (CaO), hydrated lime (Ca [OH]₂) and hydrated lime slurry, all of which can be used to treat the soils. Lime has been known to reduce the swelling potential, liquid limit, and plasticity index and it improves the workability and compaction of subgrade soils. In addition to being used alone, lime is also used with different admixtures; some of them are lime-fly ash, lime cement, and lime bitumen. In general, lime stabilization improves the strength, stiffness, and durability of fine-grained soils. (Arora, 2003) This method of stabilization has gained more attention in recent times since it has

widespread availability to be used alone or with other cementitious additives. It is inexpensive has a long history of use as an engineering material and has been successfully employed in geotechnical applications. Fly ash can improve the California bearing ratio (CBR) and Direct shear test while lowering the liquid limit and plasticity index.

2.7 Waste Materials as Stabilizers

The utilization of waste materials as stabilizers in construction has gained traction due to its potential to address environmental concerns, reduce waste, and improve soil properties. These waste materials, often byproducts of industrial processes, can be repurposed to enhance soil stability, mitigate collapsibility, and contribute to sustainable construction practices.

2.7.1 Benefits of Waste Materials as Stabilizers

- ✓ **Waste Reduction:** By repurposing waste materials that would otherwise end up in landfills, this approach contributes to waste reduction and minimizes the environmental impact of disposal.
- ✓ **Resource Efficiency:** Utilizing waste materials reduces the demand for virgin resources, such as traditional stabilizing agents like cement or lime. This conserves natural resources and decreases the carbon footprint associated with resource extraction and manufacturing.
- ✓ **Cost Savings:** Waste materials are often available at lower costs compared to conventional stabilizers. This can lead to potential cost savings in construction projects, making them economically viable alternatives.
- ✓ **Circular Economy:** Incorporating waste materials into construction aligns with the principles of the circular economy, promoting the reuse and repurposing of materials to create a closed-loop system that minimizes waste generation.
- ✓ **Environmental Impact:** Waste materials can possess properties that contribute to improved soil stability, reducing the need for energy-intensive stabilization methods. This can result in lower carbon emissions and a smaller ecological footprint.

2.7.2 Types of Waste Materials Used as Stabilizers

- **Fly Ash:** an aftereffect of burning coal in power plants, when blended with soil, fly ash's pozzolanic characteristics can strengthen the soil and lessen its permeability.

Gupta and Sharma (2016) used WMD and fly ash to assess how they affect the subgrade properties of dark cotton soil. CBR strength was improved up to 200% with the addition of 15% addition of WMD. With the addition of 15% WMD, CBR strength was increased by up to 200% (Gupta & Sharma, 2016). Saygili (2015) By introducing WMD that ranged in weight from 0–30% of the soil, researchers examined the effects of WMD on clayey soils (Saygili, 2016). The findings showed that the soil's shear strength was increased with the addition of WMD, in contrast, the swell potential was significantly diminished. Bansal and Sidhu (2016) by altering its content from 0 to 30%, researchers examined the impact of WMD on the soil. The liquid restriction decreased from 31.70 to 25% while the plastic limit climbed from 17.69 to 19.26%. The ideal moisture level of the soil was also reported to have dropped from 18 to 14.10%, and the maximum dry density increased from 1.738 to 1.884 gm/cc. Additionally, CBR Value increased from 2.46 to 6.07%.

- Rice Husk Ash: An agricultural waste, rice husk ash contains silica and has been shown to improve soil compaction and strength. Sabat et al. (2011) reported that the mixing of marble dust and rice husk with soil acts as a catalyst in its stabilization. With the addition of WMD, the strength increases while the potential swelling decreases, and WMD makes the soil and rice husk ash mixture durable (Sabat & Nanda, 2011).
- Waste Marble Dust: Waste marble dust, produced during the manufacturing of marble, is a good source of calcium carbonate and has shown promise for enhancing soil properties, including lowering collapsibility. Agrawal and Gupta (2011) reportedly decreased the liquid limit, plasticity index, and shrinkage index, and increased the plastic limit and shrinkage limit, when marble dust was added to the soil to stabilize it (Agrawal, Vinay & Gupta, 2011) and Deboucha et al. (2020) examined the impact of ceramic waste and marble dust on the performance of road sub-base layer in terms of CBR, MR, and MDD. The study concluded that MD and CW combined with a small amount of OPC could be an effective alternative for soil stabilization for use in the sub-base layer of roads (Deboucha et al., 2020)

While waste materials offer promising benefits, their utilization requires careful consideration of factors such as compatibility with soil types, potential contaminants, and proper mixing ratios.

Additionally, extensive testing and research are essential to ensure that the chosen waste material effectively enhances soil properties without compromising stability. The use of waste materials as stabilizers holds great promise for sustainable soil stabilization practices. In the context of the study "The Study of Collapsible Soil Mixed with Waste Marble Dust in the Case of Adama-Awash Road Project," exploring the potential of waste marble dust as a stabilizing agent contributes to both geotechnical knowledge and environmentally responsible construction methods.

2.8 Role of Waste Marble Dust Materials as Stabilizers

Waste marble dust, a byproduct of the marble quarrying and processing industry, has gained attention as a potential stabilizing agent for various construction and geotechnical applications. This section explores the characteristics of waste marble dust and its effectiveness as a stabilizing agent for collapsible soil.

- **Waste Marble Dust Composition:** Waste marble dust is primarily composed of fine particles generated during the cutting, polishing, and grinding of marble. It consists mainly of calcite and dolomite, which are common minerals found in marble. The particle size distribution of waste marble dust can vary depending on the processing methods, but it generally consists of fine particles that can exhibit pozzolanic properties.
- **Pozzolanic Reaction:** Pozzolanic materials react with calcium hydroxide (lime) in the presence of water to form cementitious compounds. Waste marble dust, with its calcareous composition, can potentially undergo pozzolanic reactions when mixed with lime or other cementitious materials. This reaction can contribute to the development of binding agents that enhance the cohesion and mechanical properties of soil.
- **Effect on Soil Properties:** Research suggests that the addition of waste marble dust to soil mixtures can positively influence several soil properties:
 - a. **Strength Improvement:** The incorporation of waste marble dust can contribute to the formation of cementitious bonds within the soil matrix. These bonds increase soil strength, reducing susceptibility to shear failure and enhancing load-bearing capacity.
 - b. **Reduction in Collapsibility:** The pozzolanic reaction between waste marble dust and lime can decrease the sensitivity of collapsible soil to moisture changes. The improved binding

properties can mitigate the collapse mechanism by maintaining particle cohesion upon wetting.

- c. **Compaction Enhancement:** Waste marble dust can act as a filler material, improving the packing and compaction characteristics of soil. The presence of fine particles can help fill voids and reduce air gaps, leading to increased soil density.
- d. **Sustainable Utilization:** The use of waste marble dust as a stabilizing agent aligns with sustainability goals in construction and engineering. By repurposing a waste material that might otherwise pose disposal challenges, this approach contributes to waste reduction and the promotion of circular economy principles.
- e. **Environmental Considerations:** Utilizing waste marble dust in soil stabilization can potentially reduce the demand for conventional stabilizing agents, which often have environmental impacts associated with their production. Waste marble dust's potential to undergo pozzolanic reactions can contribute to reducing carbon dioxide emissions during curing, as it consumes calcium hydroxide produced during cement hydration.
- f. **Research Gaps and Challenges:** While the potential benefits of waste marble dust as a stabilizing agent are promising, further research is needed to address challenges such as optimizing the mixing ratios, assessing long-term durability, and understanding the effects on different soil types and environmental conditions.

2.8.1 Composition and Characteristics of Chemicals of Waste Marble Dust

Waste marble dust, a byproduct of the marble processing industry, exhibits a unique chemical composition and a range of physical properties that make it a potentially effective stabilizing agent for soils. Understanding its chemical makeup and inherent characteristics is crucial to comprehending its role in soil stabilization:

- ✓ **Calcium Carbonate Content:** Waste marble dust is primarily composed of calcium carbonate (CaCO_3), which typically accounts for a significant portion of its mass. Calcium carbonate is a compound known for its cementitious properties, contributing to discarded marble dust's potential for reactivity in soil stabilization.
- ✓ **Pozzolanic behavior:** Some waste marble dust samples may exhibit pozzolanic behavior, akin to pozzolans used in cementitious materials. Pozzolanic materials react with lime

(calcium hydroxide) in the presence of water to form compounds with cementitious properties, enhancing strength and durability.

- ✓ **Particle Size Distribution:** Waste marble dust consists of fine particles that often have a particle size distribution similar to that of cement. The fine particle size enables waste marble dust to effectively fill the voids between soil particles, improving compaction and overall stability.
- ✓ **Surface Area:** The large surface area resulting from waste marble dust's fine particle size contributes to its reactivity and potential for interaction with soil particles. A greater surface area facilitates more significant contact between waste marble dust and soil, promoting beneficial chemical reactions.
- ✓ **Chemical Inertness:** While the primary component is calcium carbonate, waste marble dust may also contain trace amounts of other minerals and impurities present in the original marble. It's important to assess the chemical inertness of waste marble dust to ensure that potential contaminants do not adversely affect soil properties or the environment.
- ✓ **Water Retention and Reaction:** Waste marble dust's fine particles can aid in water retention within the soil, facilitating the hydration process. The water retention characteristic allows waste marble dust to undergo cementitious reactions with other soil components, contributing to soil stability.
- ✓ **Potential Variation:** The chemical composition of waste marble dust may vary based on factors such as the type of marble, processing methods, and source location. This variation underscores the importance of conducting comprehensive testing to determine the specific properties of the waste marble dust being utilized.

The chemical composition and properties of waste marble dust provide a foundation for its potential role as a stabilizing agent in collapsible soil. Its calcium carbonate content, fine particle size, and possible pozzolanic behavior contribute to its reactivity and potential to enhance soil properties. Understanding these characteristics is essential for evaluating waste marble dust's effectiveness and compatibility with soil types, ultimately contributing to the study's exploration of sustainable soil stabilization methods.

2.9. Previous Applications and Studies of Waste Marble Dust in Stabilization

The use of waste marble dust as a stabilizing agent in various engineering applications has gained attention due to its potential to enhance soil properties and contribute to sustainable construction practices. Several previous studies and practical applications have shed light on its effectiveness and versatility:

- ✓ **Soil Improvement and Stabilization:** Research studies have investigated the use of waste marble dust as a stabilizing agent for various types of soils, including clayey, sandy, and silty soils. Studies have shown that waste marble dust can improve soil compaction, shear strength, and bearing capacity, making it a viable alternative to traditional stabilizers.

Nazir et al., 2020 report varying the amount of marble dust added to the collapsible soil (0, 10, 20, 30%, 40%, and 50%). According to the findings, with a 50% marble concentration, the ideal water content falls by 20.67%. At a marble content of 50%, the liquid limit falls by 35.41%, the frictional angle for soil that has been saturated falls by 66.09%, and the frictional angle for soil that has not been saturated falls by 54.68%. At a marble concentration of 50%, the maximum dry density rises by 5.91%, the cohesiveness for soaked soil rises by 14.2%, and the density of unsoaked soil rises by 206.7%. The collapsing potential has been discovered to be effectively controlled by the chosen marble, and at a marble content of 30%, it is decreased by as much as 64.32%. (Nazir et al., 2020)

- ✓ **Pavement Construction:** Waste marble dust has been utilized as a stabilizing agent in pavement construction projects. It has demonstrated the potential to enhance the mechanical properties of soil and reduce pavement deformations. Previous applications have highlighted its ability to contribute to the durability and long-term performance of pavements.

In developing nations, improper waste management and storage have led to environmental degradation that has accumulated over time. The use of WMD seems to be a solution for environmental issues and lowers storage expenses, as well as issues with processing waste material (Saygili, 2015). Deboucha et al. (2020) looked into how marble dust and ceramic waste affected the CBR, MR, and MDD performance of the road sub-base layer. According to the study, using MD and CW with a tiny quantity of OPC as a soil stabilizer for roads' sub-base layers could be an

efficient alternative (Deboucha et al., 2020). Sabbagh and Hadiani (2018) Utilising cement and lime with 1.5 to 3.5% replacement, the excavated debris containing destroyed building materials was stabilized. Higher percentages of cement and lime were added to stabilize in-situ soil, resulting in the achievement of desired CBR values (Sabbagh & Hadiani, 2018).

- ✓ Embankment Construction: Waste marble dust has been explored for stabilizing embankments and slopes in transportation projects. Applications have shown that waste marble dust can reduce soil erodibility and increase the stability of embankments, minimizing the risk of landslides and slope failures.

Sabat et al. (2011) reported that the mixing of marble dust and rice husk with soil acts as a catalyst in its stabilization. With the addition of WMD, WMD enhances the durability of the soil and rice husk ash combination by increasing strength while reducing potential swelling (Sabat & Nanda, 2011). Ismaiel and Hussin (2018) expanded soils were improved using bagasse ash and WMD. The results showed that WMD significantly affects the properties of expanding soils (Ahmed & Ismaiel, 2018). Agrawal and Gupta (2011) reportedly decreased the liquid limit, plasticity index, and shrinkage index, and increased the plastic limit and shrinkage limit, when marble dust was added to the soil to stabilize it (Agrawal, Vinay & Gupta, 2011).

Bhavsar and Patel (2014) WMD was blended in various amounts (from 30 to 50%) to study the swelling characteristics of expansive and collapsible soils, and the results showed that it was successful in lowering the potential for swelling and the contraction properties of black cotton soil. (Bhavsar & Patel, 2014). Mudgal (2014) observed the impact of WMD dosage (0–40%) on dark cotton soil.). The liquid limit dropped from 57.67 to 33.9%, as was observed. The plasticity index decreased with increasing WMD dosage, from 28.35 to 16.67%, and the shrinking limit increased, from 8.06 to 18.39%. Furthermore, the swell potential dropped from 66.6 to 20.0% (Mudgal et al., 2014)

Abdulla et al. (2014) examined the soils (CL and CH) at Bastora Airport and Erbil. Different weight percentages of WMD were put into the soil. The results show that a higher WMD % results in lower liquid limits, plastic limits, plasticity indices, and swelling potential.

(R. S. Abdulla & Majeed, 2014). Abdulla and Majeed (2021) by incorporating 10, 20, and 30% WMD from three distinct sources, the mechanical stabilization of expansive soil was assessed. It was determined that a rise in marble dust content reduces the swelling capacity of expansive soils (R. Abdulla & Majeed, 2021).

Gupta and Sharma (2014) compared the effects of WMD and fly ash on the subgrade properties of dark cotton soil. With a 15% increase in WMD, CBR strength was increased by up to 200% (Gupta & Sharma, 2014). Saygili (2015) by introducing WMD that ranged in weight from 0 to 30 percent of the soil, researchers examined the effects of WMD on clayey soils. (Saygili, 2015). The findings showed that adding WMD to the soil increased its shear strength while significantly lowering its swell potential.

- Sustainable Construction: Waste marble dust aligns with sustainability goals by repurposing a waste material and reducing the demand for traditional stabilizers that have higher environmental impacts. Previous studies have highlighted waste marble dust's potential to contribute to more environmentally friendly construction practices.

Kumar & and Kumar (2020) established how discarded marble dust might be used as a geometrical to enhance the geotechnical characteristics of expansive soil and particle interaction mechanisms. The findings showed that marble dust might successfully reduce and increase the soil's flexibility. The mineralogical, chemical, and elemental makeup of the marble dust, as well as the kind of soil, were the determinants in control of the interacting behavior of soils with additional marble (Kumar & Kumar, 2020). Kumar and Tamilarasan (2015) observed that the clay's optimal moisture content (OMC) increased from 18 to 24%, and the maximum dry density (MDD) increased with the addition of WMD by up to 10% before decreasing with additional additions of WMD to the soil. WMD was introduced at 5% increments in various percentages ranging from 5 to 25%. By adding WMD, the liquid limit value steadily dropped from 70% to 55%. The plastic limit value indicated a roughly 25% rise (M & Tamilarasan, 2015). Mishra et al. (2015) used quarry dust and lime in a mixture. Quarry dust production increased, resulting in a rise in OMC from 23 to 25.1%; MDD decreased from 1.83 to 1.71gm/cc. A maximum strength value of 19.60 kg/m² causes UCS to increase by the necessary 30%. The soil's propensity for swelling was reduced from 85 to 45% (Mishra et al. 2015).

The body of previous applications and studies demonstrates the potential of waste marble dust as a valuable stabilizing agent in various engineering contexts. Its effectiveness in enhancing soil properties, its alignment with sustainability goals, and its successful implementation in real-world projects highlight its viability as a solution for the challenges posed by collapsible soil. By building upon these previous studies, the research on "Collapsible Soil Mixed with Waste Marble Dust" aims to further contribute to the understanding and utilization of waste marble dust as a sustainable and effective stabilizing agent.

2.10 Review of Previous Work on Collapsible Soil

They can be found in Ethiopia in the Southern Omo River Valley and the Southern Rift Valley in the Central Land. When there are significant rains or floods near Zeway, Shashemene, Hawassa, Adama, and Wellenchiti, hydro-compaction causes the ground to become compacted, which frequently results in potholes and fissures in the ground. Collapsible soils are present in the Afar region as dunes. (ERA Democratic et al., 2013)

Enhancing the strength and durability of soil is a part of the soil stabilization process. Different densification techniques are used for this aim in rural areas and other locations that may eventually create collapsible circumstances. Cement, bitumen, or specific additives are techniques used to bond the soil particles. Conservation of energy and resources, effective recycling of solid waste, and finding new uses for waste materials are all global issues that must be addressed if the Sustainable Development Goals (SDGs) are to be achieved. Industrial byproducts can be employed alone or in combination with other resources to efficiently exploit natural resources while keeping in mind the prevention of the dumping of waste products into the environment. (Waheed et al., 2021a) In Pakistan's Khyber Pakhtun Khaw (KPK), a Northern Province, the marble market is expanding quickly. The marble reserves in the area provide 97% of Pakistan's total marble deposits. In the province, there are more than 1,500 marble processing units (MPUs), which produce large amounts of debris, including uneven bits and marble slurry. (Abdul & Iqbal, 2007) The waste marble from the marble production plants is dumped in neighboring pits or barren ground. Along with the occupation of huge land expanses, it causes major environmental risks including dust pollution. WMD is used to make materials from clay and mortars with polymer modifications and is used in the production of white cement, mosaics, mortar, and tiles. (Hwang et al., 2007)

As filling, coarse leftover marble is employed. And it can take the role of aggregate in applications for asphalt paving. Clinker can also be produced using WMD. (Akbulut & Güreş, 2007)

El-Sayed et al. (2016) revealed that marble dust can be safely substituted for gypsum up to 5% by weight in cement, showing to be a time and money-saving idea. Environmental pollution has accumulated in emerging nations as a result of improper waste management and storage. The use of WMD appeared to a solution to environmental issues and was lower construction costs while solving waste management, storage, and handling issues. (El-sayed et al., 2016)

Deboucha et al. report 2020 Investigation on the impact of marble dust and ceramic waste on the CBR, MR, and MDD performance of the road sub-base layer. According to the study, using MD and CW with a tiny quantity of OPC as a soil stabilizer for roads' sub-base layers could be an efficient alternative. (Deboucha et al., 2020)

According to Sabbagh and Hadiani's investigation, stabilizing the excavated material—which comprised demolished building components was done using cement and lime with replacement amounts ranging from 1.5 to 3.5%. To stabilize in-situ soil and achieve the appropriate CBR values, greater amounts of cement and lime were used. (Sabbagh & Hadiani, 2018)

The study demonstrates that adding marble dust and rice husk to soil aids in its stabilization. WMD makes a combination of rice husk ash and earth durable by making the strength rise while the possible swelling lowers. (James et al., 2014)

The report provides examples of how WMD and bagasse ash might be used to improve collapsible soils. The findings revealed that WMD has a major influence on the properties of soils that collapse. (Ahmed & Ismaiel, 2018)

Marble dust can be used to stabilize soil by being applied, and it has been demonstrated to decrease liquid limit, plasticity index, and shrinkage index while raising plastic limit and shrinkage limit, according to Agrawal's research. (Gupta & Sharma, 2014)

WMD was found to be effective in lowering the capacity for expansion and the limitations of black cotton soil when employed in a range of ratios (from 30 to 50%) with collapsible and collapsible soils. It was observed that the liquid restriction dropped from 57.67 to 33.9%. Escalating the use of WMD, the shrinkage limit went from 8.06 to 18.39%, and the plasticity index from 28.35 to 16.67%. Along with that, the swell potential was decreased from 66.6 to 20.0%. (Bhavsar et al., 2014)

After being combined with 10, 20, and 30% WMD from three different sources, the mechanical stabilization of collapsible soil was evaluated. It was discovered that when the quantity of marble dust rises, the expanding potential of collapsible soils decreases. Examined the effects of fly ash and WMD on the subgrade properties of the black cotton soil. CBR strength rose by up to 200% when 15% more WMD were added. (R. S. Abdulla & Majeed, 2014)

Saygili experimented by changing the content of WMD in the soil from 0 to 30%. The liquid cap was reduced from 31.70 to 25% while the plastic cap was raised from 17.69 to 19.26%. Additional results included a decrease in the ideal soil moisture content from 18 to 14.10% and an increase in the maximum dry density from 1.738 to 1.884 g/cc. Further, the ore, CBR Value rose, rising from 2.46 to 6.07%. (Saygili, 2015)

Kumar found that leftover marble dust could be used as a geometrical to improve the geotechnical properties of the collapsible soil and particle interaction mechanism. The results demonstrated that marble dust can successfully lower the likelihood of collapse and improve the soil's flexibility. The interactions between soils that had marble added to them were controlled by the mineralogical, chemical, and elemental composition of the marble dust sand soil type. (Kumar & Kumar, 2020) According to Kumar and Tamilarasan (2015), the addition of WMD to the soil increased the clay's optimal moisture content (OMC) and maximum dry density (MDD) by up to 10%. Later, the MDD declined as more WMD were absorbed into the soil. WMD was rolled out between 5% and 25% at a time. Following the addition of WMD, the liquid limit value steadily dropped from 70% to 55%. The plastic limit increased in value by about 25%. (M & Tamilarasan, 2015)

Quarry dust soaked in lime was employed by Mishra. OMC grew from 23 to 25.1% as quarry dust consumption increased, whereas MDD fell from 1.83 to 1.71g/cc. 19.60 kg/m² is the ideal strength value, and UCS rises to the required 30% level. The possibility for the soil to swell was decreased from 85 to 45%. Waheed et al. claim that by adding Calcitic Marble Powder (CMD) and Dolomitic Marble Powder (MDP) in amounts of 5, 10, 20, 30, and 50%, the geotechnical qualities of two fine-grained soils with varying flexibility were evaluated. The expansion index, C_c & C_s , and index characteristics for both soils decreased significantly with CMD and MDP. (Waheed et al., 2021a)

2.11 Research Gap

Authors	Type of tests	Effect	Gaps
(Gaaver, 2012)	Atterberg Limit, Compaction test, Shear strength test	Uniformity coefficient, Coefficient of curvature, Natural moisture content, Natural unit weight, Liquid limit, Plastic limit, and Plasticity index is 52.04, 2.95, 11, 15.38, 28.5, 13.6, and 14.9 respectively.	The influence of water inundation on the geotechnical properties of collapsible soils was demonstrated and Grain size analysis, natural unit weight, natural water content, and consistency limits were performed. California Bearing Ratio of the compacted collapsible soils was correlated to the liquid limit. Finally, the study supports the use of compaction to treat the collapsible soils before construction of the foundations. The gap of the research is that only studied the original soil there is no any stabilizing methods.
(Tewodros Dugasa, 2019)		MDD, OMC, and Degree of Compaction is 1.38g/cc, 24.4% and 76.81% respectively LL, PL and PI is 30%, 27% and 3% respectively.	In this study, index properties like Atterberg limit, particle size distribution, specific gravity, and moisture-density relationships have been carried out and CBR, Shear strength parameter not conducted.
(S. Shujaa, 2021)	Index Property and Shear strength test	Ten percent (10%) dosage of WMD has been identified as an optimum content for the target soil improvement, The mixing of WMD with the collapsible soil decreases MDD while the OMC increased for all WMD dosages, The UCS of the soil increased up to 10% addition of WMD.	The effectiveness of WMD as a stabilizer to increase the physio-chemical properties of CL-ML soil has been studied by performing a series of laboratory tests. The properties of soil samples were evaluated without and with the addition of 5, 10, and 15% WMD by weight of the soil samples. Therefore WMD not enough to conduct the test. So that to increase the ratio of WMD up to 50% for this research work.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

This chapter is concerned with the general procedure and methodology followed during desk study, detailed field and laboratory tests, data processing, and analyses to achieve the general and specific objectives of the research work successfully. The tasks that are executed for the study, including the description of the study area, sampling technique, and sample size and preparation, are indicated as shown below. Several laboratory tests have been conducted by the American Society for Testing and Materials (ASTM) and the American Association of State of Highway and Transportation Officials (AASHTO) to determine the geotechnical and microstructural properties of the treated and untreated soil samples. The experiments were carried out mainly in the Core Consulting Engineers laboratory and ICT Engineering PVT Central Laboratory in Addis Ababa and an X-ray Diffraction (XRD) test and Scanning Electron Microscopy (SEM) have been conducted in Adama Science and Technology University (ASTU) to investigate mineral and chemical composition and the microstructural properties of the natural collapsible soil and treated Collapsible soil have been done.

3.2 Description of the study area

The Study area is located in the Middle Eastern part of the country within the boundaries of the Oromia Region. The main length of the project is approximately 60KM and it starts at the existing of Adama town passes by Welenchiti and terminates around km 60 near Melkajilo Village. The location of the starting point of this road section of the project would be (E534109 & N944258, E543875 & N956366, and E564352 & N978403) or at the end of the existing Addis-Adama expressway. The study area falls within the Ethiopian Rift Valley that extends from the Northeast to the South part of the country, as part of the Great East African Rift Valley system. The area is covered in many types of volcanic rock. Most of the plain topographic formations are covered with thick residual clay and silty clay soil as a result of the weathering of the rock and subsequent erosion and deposition.

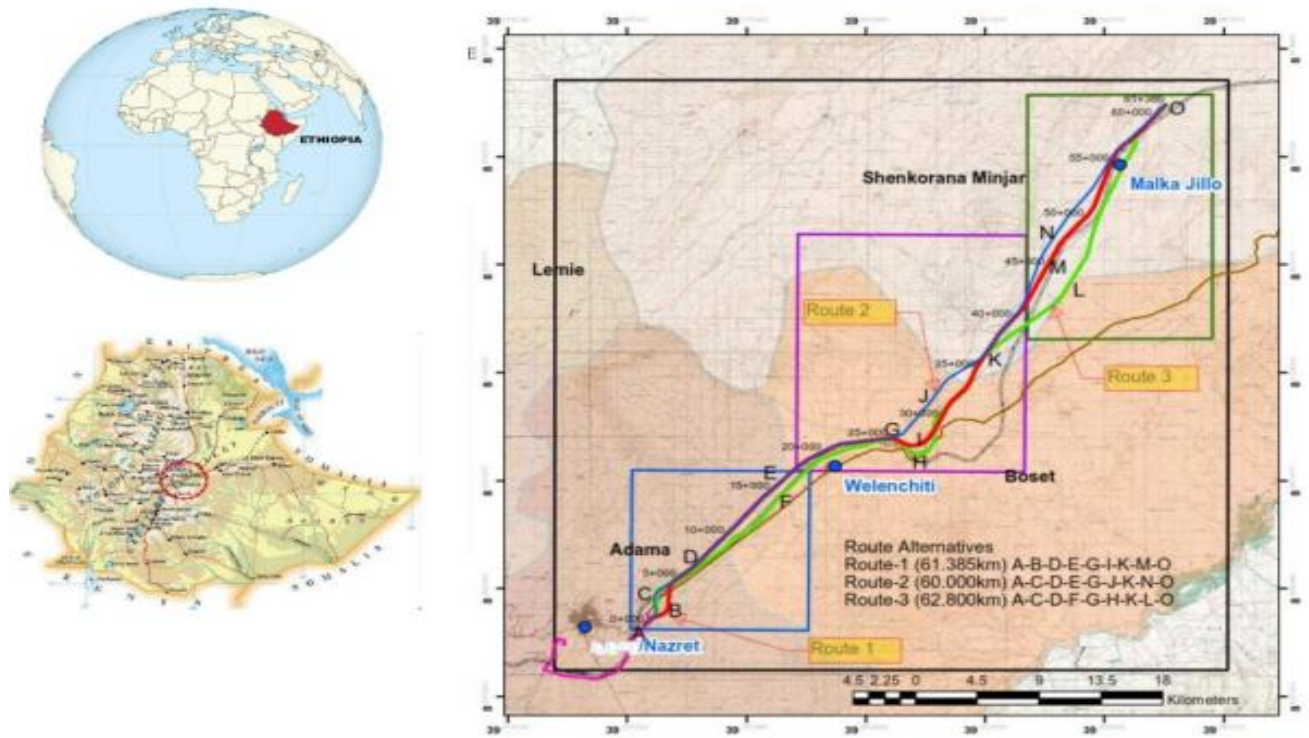


Figure 3-1: Location Map of the Study Area

3.2.1 Topography

The research study area topographic feature is dominated by flat to rolling terrain types. The Study area is generally located at an area with an altitude ranging from 1528m up to 1077m above sea level.



Figure 3.2 Elevation Profile of Study Area

3.2.2 Climate

The meteorological information about the project area was collected from the Meteorological Agency of Ethiopia website. The temperature and rainfall data of the project area was taken from thirty-five (1981-2016) years of cumulative data for Adama station. These data are mainly used to identify the rainy months of the area to incorporate the adverse effect of rainfall on the pavement design and the construction progress. Climatic conditions in Ethiopia are governed by altitudinal variations that are controlling rainfall distributions to some degree and the temperature variation largely. According to the ERA 2013 Site Investigation Manual, the climatic condition of the country is classified into five zones as shown in the table below.

Table 3.1: Ethiopian Climatic Zones (ERA 2013, Site Investigation Manual 2013.)

Climate Zone	Elevation (m)	Average Temperature (°C)	Average Annual Rainfall (mm)
Wurch (cold)	>3200	<10	<800
Dega (cool-cold)	2300-3200	10-16	1000-2000
Weina Dega (Warm-cool)	1500-2300	16-20	1200
Kolla (hot-warm)	500-1500	20-28	600 (1000 in places)
Berha (hot)	<500	28-34	<400

The project alignment is generally located at an area with altitude ranging from 1090m up to 1527m up above sea level. Accordingly, the project area is categorized under the Kolla climatic Zone with an annual mean temperature of 21.1°C to 31.0°C.

3.2.2.1 Rainfall

According to thirty-five years (1981-2016) of rainfall data collected from the Meteorological Agency of Ethiopia at Nazareth stations, the mean maximum rainfall between July and September is between 100mm to 220mm. The minimum rainfall is recorded between Novembers to January, which varies from 5mm to 10mm. The rainy season in the project area starts in June and can continue up to the end of September. The project area has an annual rainfall of 828mm.

Based on available meteorological data, the average monthly rainfall in the project area is Summarized in Table 3-2 and Figure 3-3

Table 3-2 Average Monthly Rainfall

Month	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept	Oct.	Nov.	Dec.
Rainfall, mm	10	20	50	60	60	63	220	200	100	30	10	5

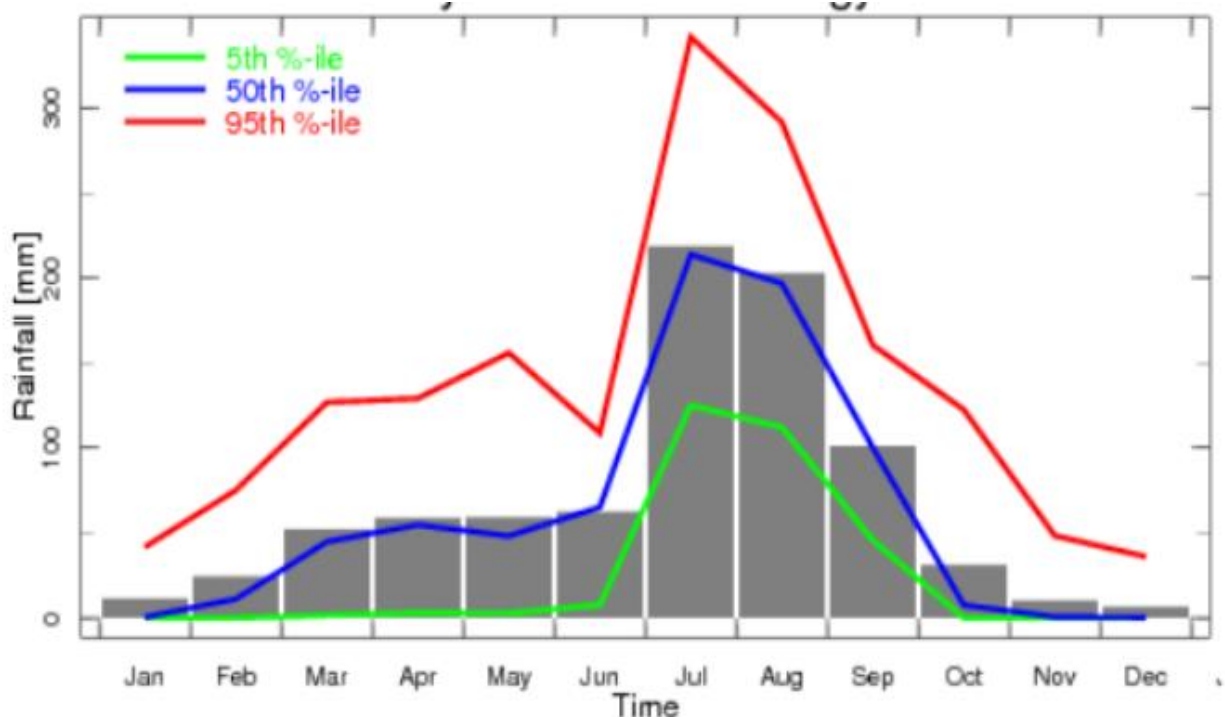


Figure 3-3 Monthly Rainfall (mm); (source NMA Website)

3.2.2.2 Temperature

Thirty-five years (1981-2016) of temperature data was collected from the Meteorological Agency of Ethiopia Nazareth stations. The maximum temperature is recorded between April to June, with the peak mean monthly value occurring in May being 31°C; and the minimum temperature is 10.8°C, which is recorded in December. The project area has an average annual temperature of 21.1°C. The monthly average maximum and minimum temperature data is shown in Table 3-3 below.

Table 3-3: Average Max and Min Temperature of the Research Area

Month	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
T. Max, °C.	27.8	29	30.3	30	31	30.3	27.2	26.8	27.9	27.8	27.2	26.9
T. Min., °C	11.8	13	14.2	14.9	15.2	15.9	15.2	15	14.5	12.2	11.4	10.8
T. Avg., °C	19.7	21	22.2	22.4	23.2	23.1	21.1	20.9	21.1	20	19.3	18.9

Monthly Maximum Temperature Climatology

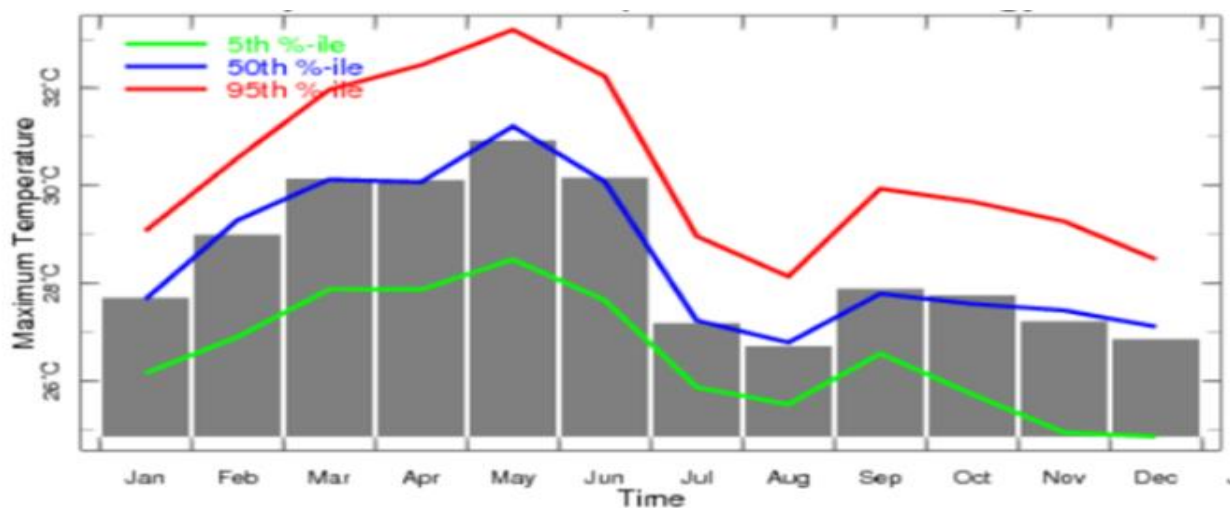


Figure 3-4: Monthly Maximum Temperature (0C), (Source: NMA Website)

Monthly Minimum Temperature Climatology

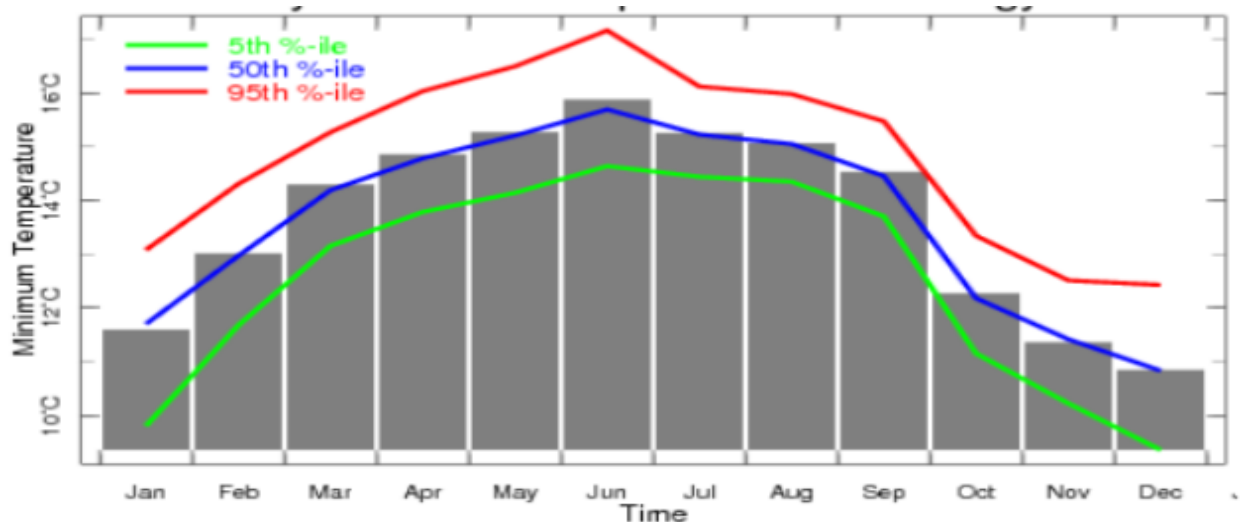


Figure 3-5: Monthly Minimum Temperature (0C), Source: NMA Website

3.3 Geological Setting

The geological formations along the selected route corridor were thoroughly investigated at desk top level before the detailed investigation using the Geological Map of Nazret (NC37-15) as obtained from the Geological Survey of Ethiopia (GSE) scaled 1:250,000. The project route corridor is entirely captured within the geological survey conducted for the Nazret area. The findings of the desk study were later refined to suit the local geology of the area assisted by a site reconnaissance survey along the proposed route corridors. Thus, the project area is dominantly covered with Nazareth Series, Nn and Basaltic and Ash Flows, Qbb.

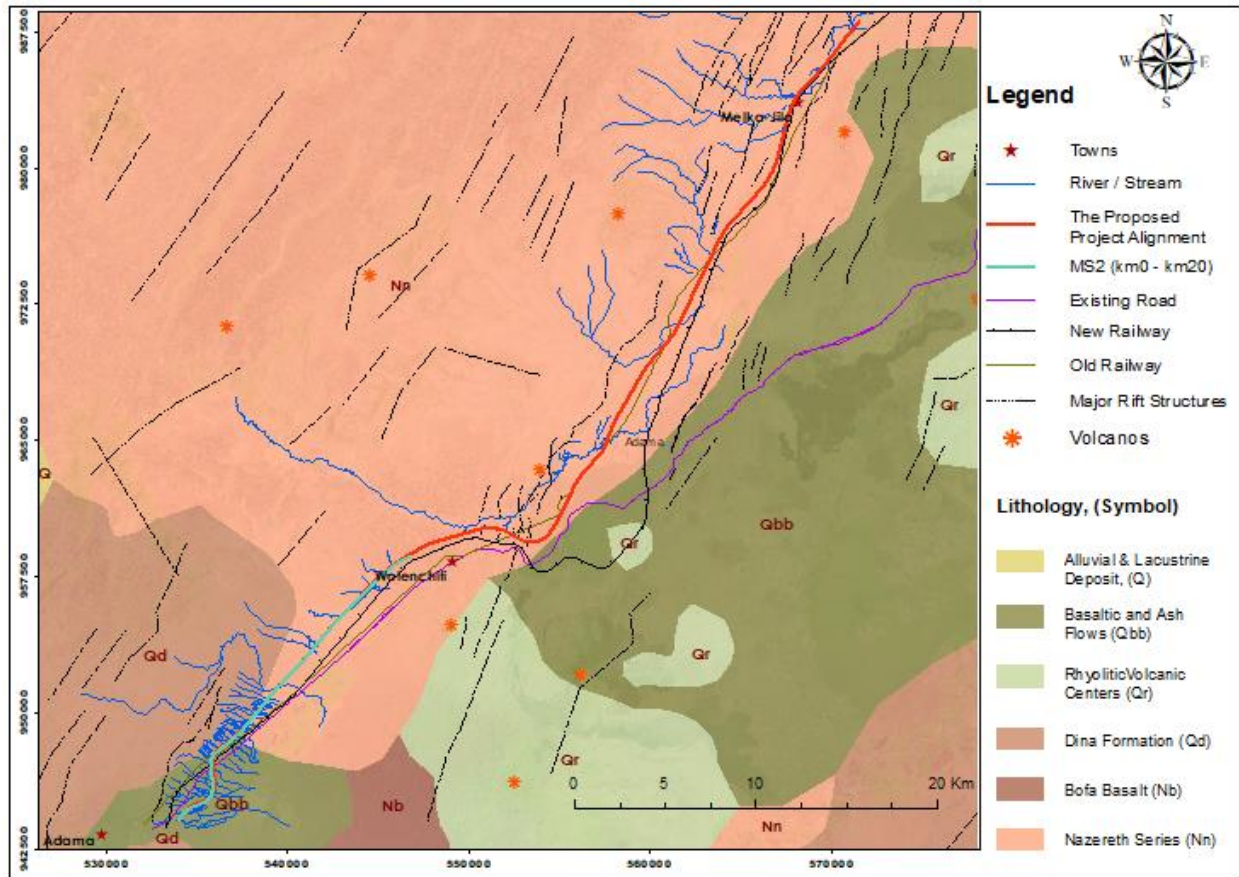


Figure 3-6 Geological Map of the Project Area

(Source: Geological Survey of Ethiopia, Geology of Nazret Area scale 1:250,000)

3.3 Study Design

This research was considered a quantitative experimental study since it was to measure the index engineering properties of soil and improvement on the soil properties by including different percentages of waste marble dust along with the durability of improved material. Four representative disturbed soil samples at of depth of 2 m were collected from different locations of the Adama-KM 60 expressway road project by random sampling technique using field observation and previous laboratory test results. A laboratory experiment program designed to conduct all of the fundamental laboratory tests to learn more about the characteristics of collapsible soil and how marble dust affects those characteristics.

The disturbed soil samples collected were then exposed to air-dried and different laboratory tests were conducted as per the American Society for Testing and Materials (ASTM) and the American Association State of Highway and Transportation Officials (AASHTO) to compare the geotechnical and microstructural characteristics between treated and untreated soil samples.

3.4 Materials

3.4.1 Collapsible Soil

The soil was collected from the Adama-KM 60 Expressway Road Project. Four study test pits were selected where the problematic soils were encountered. The sample soil was extracted at a depth of 2 m from each sample pit site, then the required number of disturbed samples was collected in plastic bags, and soil samples were transported to the laboratory after identification of collapse potential test was performed for each pit to select the weaker soil for stabilization work.



Figure 3-7 Sampling of Collapsible Soil

3.4.2 Waste Marble Dust

Waste Marble Dust taken from the local area Sendafa Marble factory. It was dried to remove all the moisture. To protect the Waste Marble Dust from degradation, moisture effect, and microbial attack, it was treated. After treating the marble, the water absorption capacity of the marble was measured. Therefore, this study was done to see the utilization impact of this marble dust from factory sludge with different percentages i.e., 10%, 20%, 30%, 40%, and 50% on collapsible soil improvement and durability. Atterberg limit, Gradation, specific gravity, Proctor test, California Bearing Ratio (CBR), and Direct Shear Test of waste marble dust were determined in the laboratory.



Figure 3.8 Waste Marble Test Preparation

3.5 Test Methods

Generally, to fulfill the study's aim, experimental testing was carried out in two steps.

- ✚ In the first phase, the properties of the untreated collapsible soil were identified the index properties like: - Atterberg limit, particle size distribution, free swell, specific gravity, standard compaction, CBR, and Direct Shear tests conducted.
- ✚ In the second phase based on the test results with different proportions of marble dust (10%, 20%, 30%, 40%, and 50%) and collapsible soil mix, index properties, standard

compaction, CBR and Direct Shear tests optimum percentage of marble dust was determined.

Table 3.4 Proportion of collapsible soil and marble dust

Serial No	Collapsible Soil	Marble Dust	Percentage
1	100% Collapsible Soil	0% marble dust	100-0
2	90% Collapsible Soil	10% Marble dust	90-10
3	80% Collapsible Soil	20% Marble dust	80-20
4	70% Collapsible Soil	30% Marble dust	70-30
5	60% Collapsible Soil	40% Marble dust	60-40
6	50% Collapsible Soil	50% Marble dust	50-50

3.6 Research Design

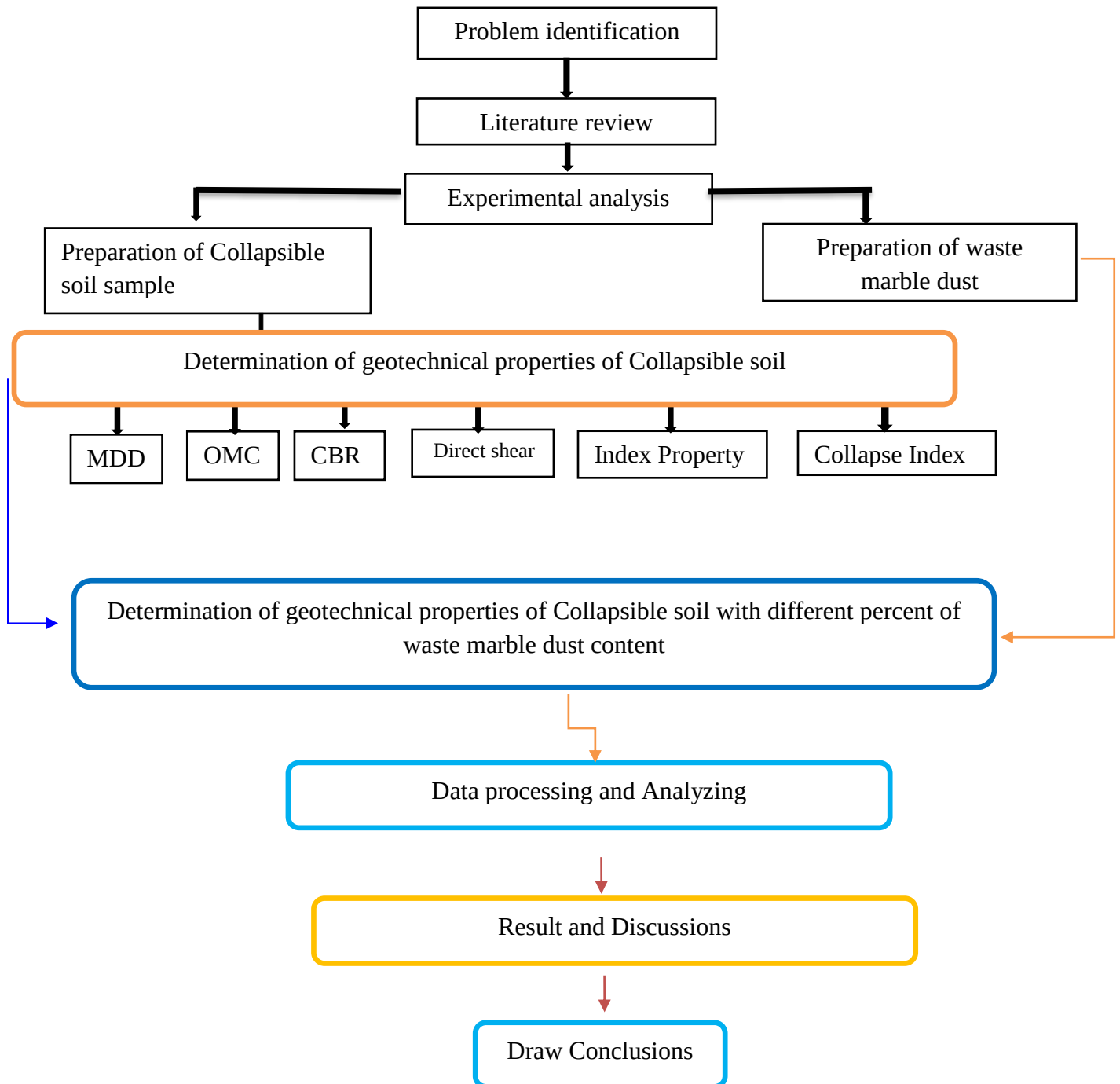


Figure 3-9 Flow chart illustrating the research methodology

3.7 Sampling Technique, Sample Size and Preparation

3.5.1 Sampling Technique

It appears that the sampling technique used in this study is indeed purposive sampling, which is a non-probability sampling method. In purposive sampling, samples are selected intentionally based on specific criteria or characteristics of interest. In your case, the samples are taken at designated intervals of every 200 meters within the LHS (Left-Hand Side), CL (Central Line), and RHS (Right-Hand Side) sections. This approach allows for targeted sampling at predetermined locations, which aligns with the research objectives and criteria set for the study.

3.4.2 Sample Size

The soil samples were excavated and collected at a depth of 2 meters below the natural ground level to acquire a representative collapsible soil sample. Following the outlined criteria, samples were obtained from 26 specific locations spanning from kilometer marker 7+300 to 12+300, with each location corresponding to an individual pit investigated. Among these pits, the one exhibiting the highest collapsible index was selected for a thorough examination. Detailed XY coordinates for each of the sample test pits are provided in Annex 1.

3.4.3 Sample preparation

The disturbed sample is employed for the identification of soil components, general classification purposes, and certain engineering property assessments, including the Atterberg Test (Plastic Limit, Liquid Limit, and Plastic Index), particle grain size distribution analysis, and compaction testing. In contrast, the undisturbed sample comprises material extracted from the site and transported to the laboratory with minimal disturbance. Undisturbed soil samples are essential for conducting laboratory tests such as one-dimensional consolidation tests.



Figure 3-10 Sample preparation of collapsible soil

Based on the criteria mentioned, soil samples were obtained from four different pits, and the first step upon transporting these soil samples to the laboratory was to reduce the size of the larger particles to a more manageable level. Following the guidelines outlined in the specified laboratory manuals, which adhere to both ASTM and AASHTO standards, the soil samples underwent a sieving process. This sieving process was conducted to prepare specimens with the appropriate sizes required for various laboratory tests. Subsequently, a predetermined vertical stress was applied to the specimens, and they were saturated with a fluid to induce the potential collapse of the soil specimen. The collapse index was determined by measuring the settlement at an applied vertical stress of 200 kPa. The resulting collapse index values were then utilized to categorize the soil into different degrees of collapse, as outlined in the classification system specified by ASTM D-5333.

In summary, the laboratory testing procedures followed a systematic approach, conforming to established standards, to assess the collapse behavior of the soil samples and classify them based on their respective collapse index values.

3.4.4 Data Collection

Collapsible soil samples were obtained using a combination of manual and mechanical methods. Manual collection involved tools like pickaxes, head pans, and shovels, while an excavator was employed for excavation purposes. These samples were acquired at a depth of 2 meters below the natural ground surface. In preparation for conducting one-dimensional consolidation tests, the collected soil samples underwent a remolding process. This ensured that the samples were suitably conditioned for the specific testing procedures. In addition to the primary data derived from laboratory tests, a supplementary set of secondary data was sourced from various references, including articles, prior research literature, and diverse manuals. This comprehensive approach facilitated a thorough analysis and evaluation of the obtained results within the broader context of existing knowledge and reference materials.

3.5 Laboratory Tests

The collected soil sample was exposed to air, dried, and then pulverized into the required size before conducting the laboratory tests. Then the laboratory tests conducted on both the untreated collapsible soil and collapsible soil with marble dust samples are specific gravity, plasticity index, particle size distribution, compaction, swelling index, direct shear test, collapsible index and

chemical tests are conducted as per the American Society for Testing and Materials (ASTM) and AASHTO standards.

Table 3. 5 Summary of Untreated Collapsible Soil laboratory test result

Liquid limit	AASHTO T 89	43.25%
Plastic Limit	AASHTO T 90	28.69%
Plasticity index	AASHTO T 90	14.56%
Specific gravity	AASHTO T100-16	2.609
Maximum dry density	AASHTO T 180	1.44
OMC	AASHTO T 180	18.2%
CBR value	AASHTO T 193	22%
Collapsible Index	ASTM D 5333	9.08
Soil classification	ASTM D 2487	CL-ML
Particle size distribution	ASTM D 6913	Sand (99%), Silt and Clay (1%)
Cohesion C, Unsoaked	ASTM D3080-11	22
Cohesion C, Soaked	ASTM D3080-11	20.6
The angle of Internal Friction (φ) Unsoaked	ASTM D3080-11	13.82
Angle of Internal Friction (φ) Soaked	ASTM D3080-11	14.68

3.5.1 Natural Moisture Content

The moisture content of the soil samples was determined according to AASHTO T-89-17 procedures, while the moisture content (w) was determined in the laboratory. The moisture content of a soil mass is defined as the ratio of the weight of water (W_w) to the weight of solids (dry weight W_s) of the soil mass.

$$w = (W_w/W_s) * 100$$

Drying oven, Balance, Moisture can, and Container Handling Apparatus (gloves, tongs) were used to conduct this test.

3.5.2 Specific gravity test

The weight of a particular volume of a material divided by the weight of an equivalent volume of distilled water is used to determine the specific gravity of a material. The soil sample is a pass of the No. 40 (425 μ m) sieve and it is determined by ASTM Test Designation (ASTM D-854, 2002). Thus, specific gravity, G_s is defined as:

$$G_s = \text{unit weight (or density) of soil solids only} / \text{unit weight (or density) of water}$$

The result of the treated and untreated collapsible soil sample of specific gravity is attached in Appendix A.



Figure 3-11 Specific Gravity

3.5.3 Atterberg limit tests

Atterberg limit tests have liquid and plastic limit tests which are carried out by (ASTM D-4318, 2010), and a soil specimen that is finer than the No. 40 (425 μ m) sieve is used. The liquid and plastic limits of soil samples for untreated soil and treated soil were measured by the combined method of liquid and plastic limits. Finally, plastic index PI is measured by subtracting the plastic limit from the liquid limit, which is the moisture content range in which soil behaves plastically. It's an important parameter to determine the expansiveness index and classify fine-grained soils.

The result of the natural expansive soil sample of liquid plastic limit and shrinkage limit is attached in Appendix B.



Figure 3-12 Atterberg Limit Test and Sample Preparation

3.5.4 Particle Size Distribution

Grain size distribution divides soils into two distinctive groups, namely fine-grained and coarse-grained soils. Soil particles coarser than 0.075mm, are generally termed as coarse-grained whereas soil particles finer than 0.075mm like clays and silts are termed as fine-grained. The particle size distributions can be done by using two methods: sieve analysis for particle sizes larger than 0.075mm (No. 200) in diameter, and hydrometer analysis for particle sizes smaller than 0.075mm in diameter. The particle size distribution of the NES sample is attached in Appendix B.

3.5.4.1 Sieve Analysis

Sieve analysis is a method used to determine the grain size distribution of soils. Sieves are made of woven wires with square openings. To classify soil for engineering purposes, one needs to know the distribution of the size of grains in a given soil mass. The particle size distribution is determined by (ASTM D-421, 1998). This enabled a continuous particle size distribution curve to be plotted from the size of the coarse (gravel) particles down to the finest (clay) size. A plot on a semi-logarithmic chart was then done of the percentage of material passing each sieve against the sieve sizes to give the grading.



Figure 3-13 Sieve Analysis test

3.5.5 Proctor test

The compaction test procedure is used to determine the maximum dry unit weight of compacted soils which can be used for specification of field compaction. The Proctor (Compaction) test is carried out by AASHTO T180 and helps to decrease compressibility, increase shear strength and bearing capacity, and sometimes decrease the permeability of soils for engineering construction (AASHTO T180).

The variation of maximum dry density and optimum moisture content for natural and treated soil samples are plotted, presented, and discussed in the next chapter, and the laboratory datasheet of compaction test results for the raw soil is tabulated in Appendix B.



Figure 3-14 Proctor Test

3.5.6 XRD Test

The X-ray diffraction test was done on soil samples after being grained to a fine powder pass of the No 200 sieve to analyze the mineralogical phase of soil samples. The samples were scanned at an angle of 2θ ; a range from 10° to 80° was chosen to provide enough XRD peaks to identify the most common minerals. MATCH software (MATCH, 2014) was used to analyze the data obtained from the diffractometer.

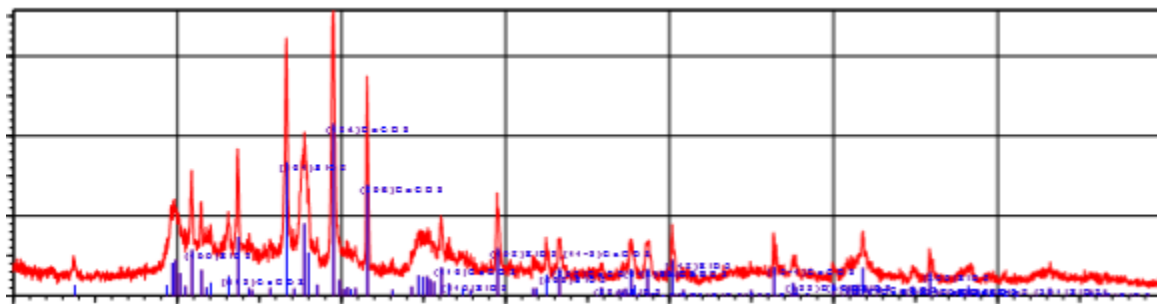


Figure 3-15 XRD Test result for Collapsible Soil

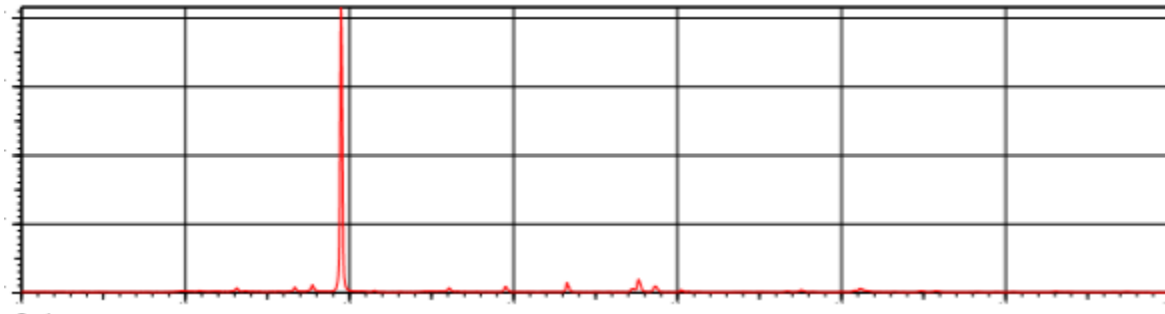


Figure 3-16 XRD Test result for Marble

3.5.7 Collapse Index Test

The Collapse Potential Test another name for the Collapse Index Test, is a geotechnical laboratory test used to assess the potential for collapsible soils to undergo volume reduction and settling in response to variations in the moisture content. Collapsible soils are typically composed of fine particles, such as silts and clays, and exhibit a significant reduction in volume and strength when they absorb water. The Collapse Index Test is conducted to determine the susceptibility of soil to collapse upon wetting. This is particularly important in geotechnical engineering when designing foundations, embankments, and other structures, as unexpected settlements due to soil collapse can lead to structural instability and damage.

The representative samples were selected, and the specimen at natural moisture content was placed in a consolidometer, applying a predetermined vertical stress to the specimen and inundating the specimen with fluid to induce a potential collapse in the soil specimen. The collapse index was computed as the settlement at an applied vertical stress of 200 kPa. The result was used to categorize the soil into different degrees of collapse. The classification of the collapse index as per ASTM D-5333 was presented and tabulated in Appendix B

The Collapse Index Test typically involves the following steps:

soil sample is collected from the field or obtained from drilling. The sample is carefully preserved and transported to the laboratory in an undisturbed state to maintain its natural structure. The undisturbed soil sample is initially dried and weighed. It is then saturated with water by gradually adding water to the sample until it reaches a specified moisture content. This process is done slowly to simulate natural wetting. Once the sample is fully saturated, it is allowed to air-dry under

controlled conditions. The sample is left to dry until it reaches an equilibrium moisture content or until no further volume change is observed. Throughout the drying process, the volume of the soil sample is carefully monitored. This is often done using a volume displacement apparatus that can measure changes in volume accurately.

The Collapse Index is calculated as the ratio of the reduction in volume (during drying) to the initial volume of the saturated soil sample. It is expressed as a percentage.

$$\text{Collapse Index (\%)} = [(\text{Initial Volume} - \text{Final Volume}) / \text{Initial Volume}] \times 100$$

Table 3.6 Collapse index test result

No	Station	Representative stretch	Depth (cm)	Collapse Index	Degree of Collapse
1	7+300	7+200 - 7+400	0 – 100	4.1	Moderate
2			100 - 200	5.8	
3	7+500	7+400 - 7+600	0 – 100	1.3	Slight
4			100 - 200	2.2	Moderate
5	7+700	7+600 - 7+800	0 - 200	9.1	Moderately Severe
6	7+900	7+800 - 8+000	0 – 100	2.5	Moderate
7			100 - 200	3.3	
8	8+100	8+000 – 8+200	0 – 100	1	
9			100 - 200	1.7	
10	8+300	8+200 – 8+400	0 - 200	1.3	
11	8+500	8+400 – 8+600	0 – 100	1.4	
12			100 - 200	1.2	Slight
13	8+700	8+600 – 8+800	0 – 200	0.3	
14	8+900	8+800 – 9+000	0 – 100	4.4	
15	9+100	9+000 – 9+200	0 – 100	2.2	
16	9+300	9+200 – 9+400	0 – 100	4.4	Moderate
17			100 - 200	5.1	
18	9+500	9+400 – 9+600	0 - 200	3.2	
19	9+700	9+600 – 9+800	0 – 200	0.3	
20	9+900	9+800 – 10+000	0 - 200	1.3	Slight
21	10+100	10+000 – 10+200	100 - 200	6.1	Moderately Severe
22	10+300	10+200 – 10+400	0 - 200	2.5	Moderate
23	10+500	10+400 – 10+600	0 - 200	1.2	Severe
24	10+700	10+600 – 10+800	0 - 200	2.1	Moderate
25	10+900	10+800 – 11+000	0 - 200	0.8	
26	11+100	11+000 – 11+200	0 - 200	0.8	
27	11+300	11+200 – 11+400	0 - 200	1	
28	11+500	11+400 – 11+600	0 - 200	0.3	

29	11+700	11+600 – 11+800	0 - 200	1.2	Moderate Slight
30	11+900	11+800 – 12+000	0 - 200	5.8	
31	12+100	12+000 – 12+200	0 - 200	3.6	
32	12+300	12+200 – 12+400	0 - 200	1.5	



Figure 3-15 Collapse index test

The Collapse Index value provides information about the potential for collapse in the soil. A higher Collapse Index indicates a greater susceptibility to collapse upon wetting. The test results help engineers and geologists assess the risk of settlement and volume reduction in collapsible soils when subjected to changes in moisture content.

3.5.9 Direct Shear Test

The test is carried out on either undisturbed samples or remolded samples. To facilitate the remolding purpose, a soil sample may be compacted at optimum moisture content in a compaction mold. Then specimen for the direct shear test could be obtained using the correct cutter provided.

Alternatively, sand samples can be placed in a dry state at a required density, in the assembled shear boxes.

A normal load is applied to the specimen and the specimen is sheared across the pre-determined horizontal plane between the two halves of the shear box. Measurements of shear load, shear displacement, and normal displacement are recorded. The test is repeated for two or more identical specimens under different normal loads. From the results, the shear strength parameters can be determined. The strength of soil depends on its resistance to shearing stresses. The test result for the direct shear test is tabulated in Appendix C.



Figure 3-16 direct shear test

3.5.10 California Bearing Ratio Test (CBR)

CBR test was conducted to assess the potential quality of subgrade, subbase, and base course material, including reusable materials for use in road pavements and landing strips (Waheed et al., 2021b).

Waste marble dust was added to the soil in percentages of (10, 20, 30, 40, and 50%) respectively. A total of 24 molds were prepared for soaked CBR. For each specimen, three molds were prepared with 10, 30, and 65 blows, and CBR values were calculated against 95% MDD. CBR tests were carried out by the standard method of (AASHTO-T-193, 2007). A newly calibrated, electrically operated CBR machine was used with a ring constant of 10 lbs and a plunger diameter of 3-inch square, and the test results are tabulated in Appendix B.



Figure 3-17 CBR Test and prepared sample

3.5.11 Swell Potential

The swelling potential of collapsible soil samples was determined after 96 hours of soaking the molds. The swell potential of 24 CBR samples prepared with 10, 30, and 65 blows respectively against 0, 10, 20, 30, 40, and 50% dosages of WMD were determined with the help of dial gauges. Three dial gauges of 0.01mm least count were installed on each sample, and the average value of three gauges has been reported using AASHTO T193.



Figure 3-18 Swelling Index Test

3.6 Data Processing and Analysis

The laboratory test results of both treated and untreated soil were discussed

- In processing and analysis, a literature review of research papers and data from laboratory results was analyzed to come up with an output.
- Laboratory results were checked for accuracy and were compared to the output with the available standard specifications.
- Finally, the organization and presentation of the results of the analysis were done by the research objective.

CHAPTER 4

RESULT AND DISCUSSION

Samples were gathered from test trenches located at 7+700, 2 m below the existing ground level, as was indicated in the chapter before. We examined the collapsible index (7+300-12+300), and we selected the severe outcomes that appear at 7+700. Field densities were immediately measured. Additionally, disturbed undisturbed samples were taken out and brought to the main consulting engineering laboratory for the necessary lab tests. This chapter explores deeply into the outcomes of field and lab investigations.

4.1 Field Density Test

The in-situ bulk density parameters of the subgrade at the sampling locations were studied by conducting density tests based on the AASHTO T-191 (1993) testing protocol for the density of soils utilizing the sand replacement method. In addition, the natural moisture contents of the soil samples were evaluated using AASHTO T-265. These moisture content measurements were utilized to compute the field dry densities. The results of these tests are shown in Table 4.1

Table 4.1 Field dry density of soil

Station	Field Bulk Density (g/cc)	Field Dry Density (g/cc)	Field moisture content (%)
7+500	1.35	1.15	18.2

The results show that the subgrade soils have very low bulk and dry densities. The densities from the test pits are below the proposed boundaries of Clevenger (1958)-1.28 g/cc, indicating, as discussed in the literature review, that the soil is prone to severe settlement. Similarly, according to the ERA's 2013 Geotechnical Design Manual, the densities are less than 1.6 g/cc, making them prone to collapse.

4.2 Particle Size Distribution

The particle size distribution is typically represented by a grain size distribution curve, which shows the percentage of soil particles that pass through different sieve sizes. To create the grain size distribution curve, the cumulative percent retained values from the data is used. The

cumulative percent retained represents the percentage of soil particles that are retained on or pass-through a given sieve size.

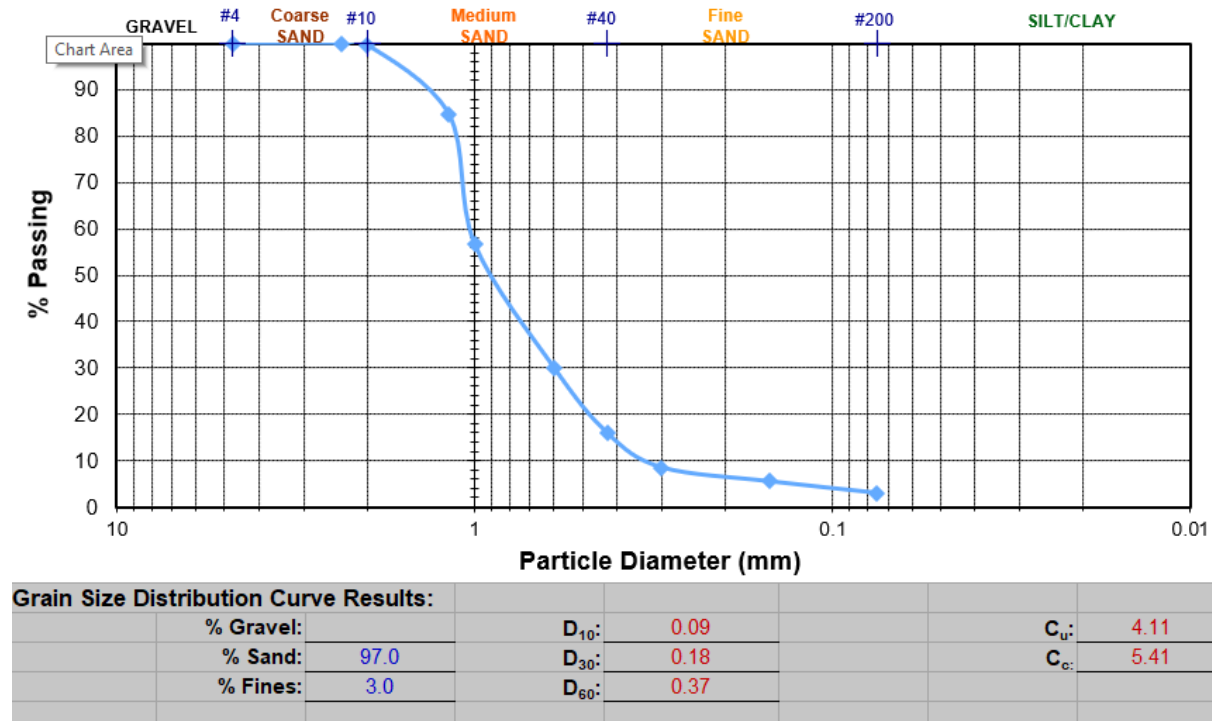


Figure 4.1 Particle size distribution of marble

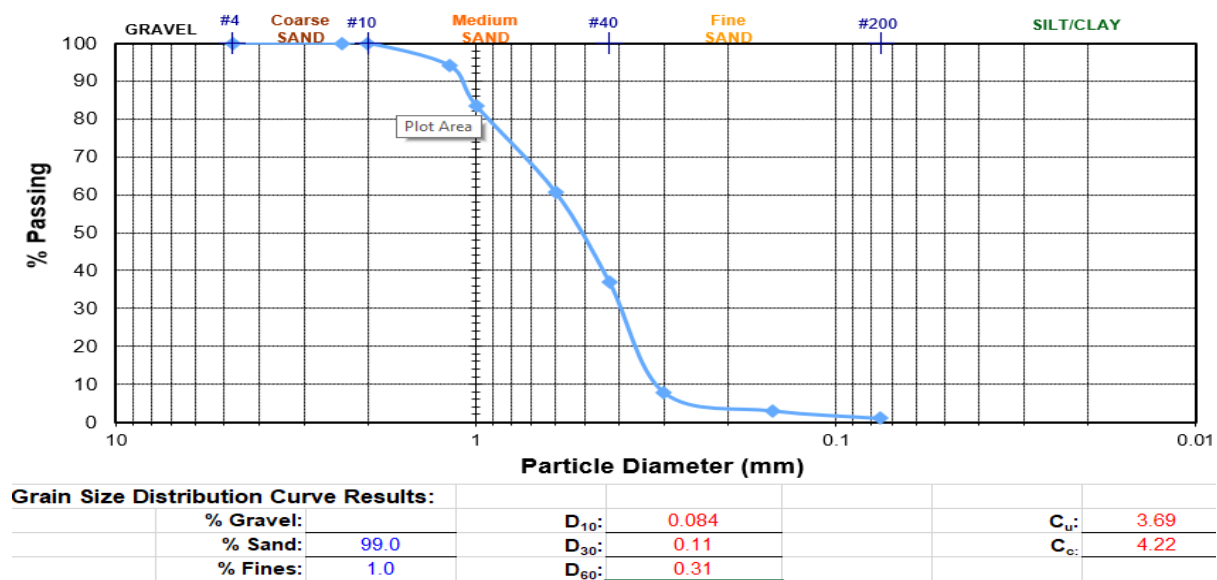


Figure 4.2 Particle size distribution of soil

These results provide insights into the particle size distribution and characteristics of the collapsible soil. The high percentage of sand particles suggests that the soil may have good drainage properties. The presence of fines (silt and clay) indicates that the soil may have some cohesive properties. The coefficients of uniformity and curvature provide information about the range and shape of the grain size distribution curve.

4.3 Specific Gravity

The samples recovered from the 7+500 test pit and marble were subjected to certain gravity tests. The specific gravities of the marble and soil are 2.728 and 2.558, respectively. Based on the test results, the specific gravity of the soil sample was determined to be 2.558, while the specific gravity of the marble sample was found to be 2.728. These values indicate the relative density or heaviness of the materials compared to the density of water.

The specific gravity of the soil sample suggests that it is relatively lighter compared to water, indicating a lower density. This could be attributed to the composition and characteristics of the soil, such as the presence of organic matter or porous structure. It is important to note that specific gravity can vary depending on factors such as moisture content and compaction, so further testing and analysis may be required to understand the soil's behavior and properties more comprehensively. On the other hand, the specific gravity of the marble sample indicates that it is relatively heavier compared to water, suggesting a higher density. This is expected as marble is known for its dense and solid nature. The specific gravity value of 2.728 aligns with the typical range for marble, further confirming the accuracy of the test.

The specific gravity of the marble remained relatively constant at 2.609, except for the 50% moisture content, where it increased to 2.72. This suggests that the moisture content has a minimal effect on the specific gravity of the marble.

4.4 Atterberg Limit

The liquid limit represents the moisture content at which the soil transitions from a liquid-like state to a plastic state. As the moisture content increases, the liquid limit decreases, indicating that the soil becomes more plastic. This is evident from the decreasing values of the liquid limit from 43.25% at 0% moisture content to 27.42% at 50% moisture content.

The plastic limit represents the moisture content at which the soil transitions from a plastic state to a semi-solid state. Similar to the liquid limit, as the moisture content increases, the plastic limit decreases. This is evident from the decreasing values of the plastic limit from 28.69% at 0% moisture content to 19.2% at 50% moisture content.

The plastic index is the difference between the liquid limit and the plastic limit and represents the range of moisture content over which the soil exhibits plastic behavior. As the moisture content increases, the plastic index decreases, indicating a narrower range of plastic behavior. This is evident from the decreasing values of the plastic index from 14.56% at 0% moisture content to 8.22% at 50% moisture content.

These test results provide valuable information about the plasticity characteristics of the soil. They can be used to assess the soil's behavior and suitability for various applications, such as construction and engineering projects. It is important to note that these results are specific to the tested soil sample and may vary for different soil types. Therefore, further testing and analysis are recommended to understand the soil's behavior more comprehensively.

The liquid limit of the marble decreased as the moisture content increased. At 0% marble content, the liquid limit was 43.25%, which decreased to 27.42% at 50% marble. This indicates that the marble becomes less susceptible to liquefaction with the addition of moisture.

The plastic limit and plastic index of the marble also decreased as the moisture content increased. This implies that the marble becomes less plastic and more brittle with the addition of moisture.

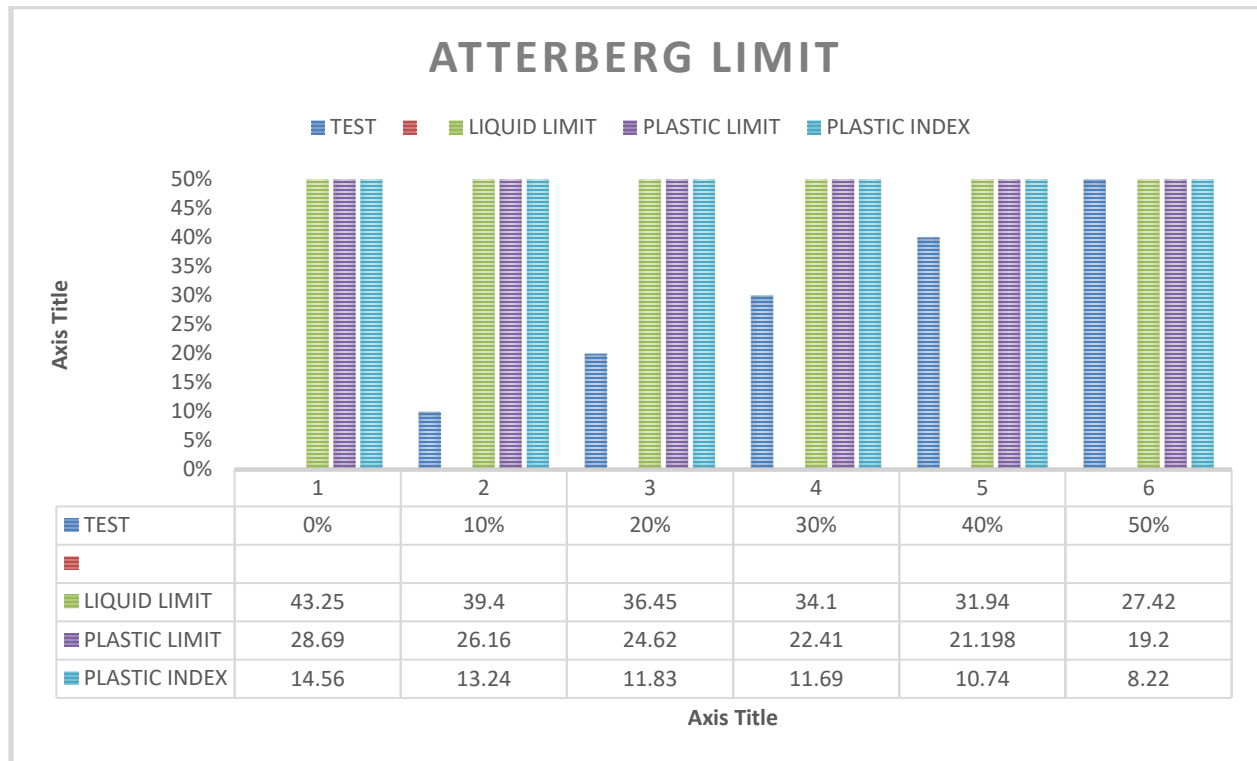


Figure 4.3 Plastic Index Graph

4.5 Maximum dry density and optimum moisture content

The maximum dry density of the marble sample increased as the moisture content increased. At 0% marble content, the maximum dry density was 1.44 g/cm³, which gradually increased to 1.836 g/cm³ at 50% marble content. This indicates that the marble becomes more compact and denser with the addition of moisture.

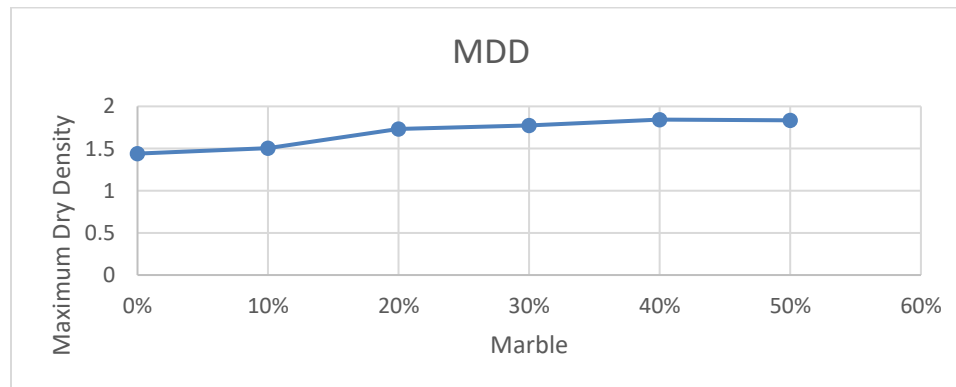


Figure 4-4 Maximum Dry Density Chart

The optimum moisture content of the marble decreased as the percentage of marble content increased. At 0% marble content, the optimum moisture content was 18.2%, which decreased to 5.8% at 50% marble content. This suggests that the marble requires less water to reach its maximum density as the moisture content increases.

4.6 California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) test is used to evaluate the strength and load-bearing capacity of soil and aggregate materials. It is commonly used in geotechnical engineering to assess the suitability of soil for road construction and pavement design.

From the test results, it can be observed that the CBR values increase with increasing moisture content up to a certain point. At 0% moisture content, the CBR value is 22, which indicates a relatively lower strength and load-bearing capacity of the soil. As the moisture content increases to 10%, 20%, and 30%, the CBR values also increase to 25, 27, and 39, respectively. This suggests an improvement in the soil's strength and load-bearing capacity with the addition of moisture.

However, beyond a certain moisture content, the CBR values start to decrease. At 40% moisture content, the CBR value drops to 35.5, and at 50% moisture content, it further decreases to 31.5. This decrease in CBR values at higher moisture contents can be attributed to the excessive saturation of the soil, leading to reduced cohesion and increased pore water pressure, which negatively affect the soil's strength and load-bearing capacity.

It is important to note that the specific moisture content at which the CBR value starts to decrease may vary depending on the soil type and composition. Therefore, further testing and analysis are recommended to determine the optimum moisture content for achieving the highest CBR value and ensuring optimal performance in road construction and pavement design. Overall, the CBR test results provide valuable information about the strength and load-bearing capacity of the soil at different moisture contents. These results can be used to make informed decisions regarding soil stabilization techniques and the design of road and pavement structures to ensure their long-term stability and durability.

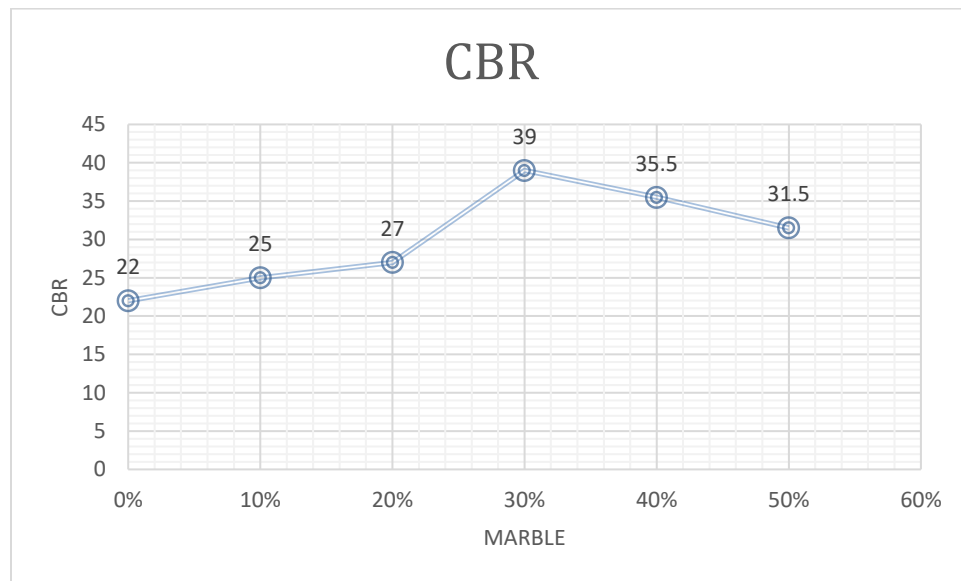


Figure 4.16 CBR Test Result Graph

The CBR value of the marble increased as the marble increased up to 30%, after which it started to decrease. This suggests that the marble exhibits the highest resistance to deformation at 30% marble content.

4.7 Swelling index

The swelling index of the soil sample with marble dust decreased initially and then increased as the marble content increased. This indicates that the marble undergoes minimal swelling at lower marble contents, but starts to swell slightly again at higher marble contents.

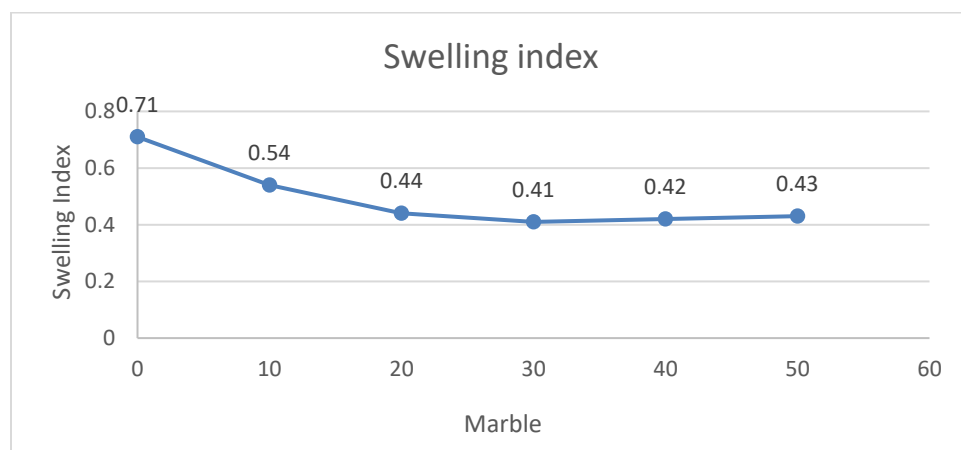


Figure 4-17 Swelling Index Test Result

4.8 Collapsible Index

The collapsible index is a measure of the potential for soil to undergo significant volume change and settlement under load. It is calculated by dividing the difference between the natural moisture content and the liquid limit by the liquid limit and multiplying by 100. The higher the collapsible index, the greater the potential for soil collapse.

Based on the provided data, the collapsible index values for different moisture contents are as follows:

- 0%: 9.08
- 10%: 7.42
- 20%: 5.13
- 30%: 3.11
- 40%: 2.7
- 50%: 1.2

From the results, it can be observed that as the moisture content increases, the collapsible index decreases. This indicates a lower potential for soil collapse and settlement under load. At 0% moisture content, the collapsible index is 9.08, which suggests a relatively higher potential for soil collapse. However, as the moisture content increases to 10%, 20%, and 30%, the collapsible index decreases to 7.42, 5.13, and 3.11, respectively. This indicates a decreasing potential for soil collapse with increasing moisture content. Furthermore, at 40% and 50% moisture content, the collapsible index continues to decrease to 2.7 and 1.2, respectively. These values suggest a significantly lower potential for soil collapse and settlement under load at higher moisture contents. The results of the collapsible index provide important information about the soil's behavior and its suitability for construction purposes. A lower collapsible index indicates a more stable soil that is less prone to significant volume changes and settlement under load. This information can be used to make informed decisions regarding foundation design and construction methods to ensure the long-term stability and durability of structures.

The collapsible index of the marble decreased as the marble content increased. This implies that the marble becomes less prone to collapse with the addition of moisture

4.9 Direct Shear Tests

The cohesion and angle of internal friction are important parameters in geotechnical engineering that characterize the shear strength and stability of soil. From the test results, it can be observed that both the cohesion and angle of internal friction decrease with increasing moisture content. For the unsoaked condition, the cohesion decreases from 22 kPa at 0% marble content to 14.2 kPa at 50% marble content. Similarly, the angle of internal friction decreases from 13.82 degrees at 0% marble content to 20.6 degrees at 50% marble content.

For the soaked condition, the cohesion decreases from 20.6 kPa at 0% marble content to 13.6 kPa at 50% marble content. The angle of internal friction decreases from 14.68 degrees at 0% marble content to 21.2 degrees at 50% marble content. The decrease in cohesion and angle of internal friction with increasing marble content can be attributed to the reduction in inter-particle forces and increased pore water pressure. As the soil becomes more saturated, the water fills the void spaces between particles, reducing the effective stress and the soil's shear strength.

These results suggest that the soil's shear strength and stability decrease with increasing moisture content. It is important to consider these findings in geotechnical engineering projects, particularly in slope stability analysis, foundation design, and earthwork construction. Adequate measures such as drainage systems, soil stabilization techniques, or changes in construction methods may be necessary to mitigate the potential instability and reduce the risk of failure in wet or saturated conditions. It is worth noting that the specific values of cohesion and angle of internal friction can vary depending on the soil type and composition. Therefore, further testing and analysis are recommended to obtain a more comprehensive understanding of the soil's shear strength characteristics and make accurate engineering decisions.

The cohesion and angle of internal friction of the marble decreased as the moisture content increased. This indicates that the marble becomes less cohesive and has a lower resistance to shear stress with the addition of moisture.



Figure 5.1 Direct Shear Tests

Here are the full test results for the direct shear tests conducted on the collapsible soil with varying marble content:

Marble Content: 0%

- Cohesion (Un soaked): 22
- Cohesion (Soaked): 20.6
- Angle of Internal Friction (Un soaked): 13.82
- Angle of Internal Friction (Soaked): 14.68

Marble Content: 10%

- Cohesion (Un soaked): 20.2
- Cohesion (Soaked): 18.84
- Angle of Internal Friction (Un soaked): 15.1
- Angle of Internal Friction (Soaked): 16.33

Marble Content: 20%

- Cohesion (Un soaked): 18.3
- Cohesion (Soaked): 17.4
- Angle of Internal Friction (Un soaked): 16.91
- Angle of Internal Friction (Soaked): 17.43

Marble Content: 30%

- Cohesion (Un soaked): 16.9
- Cohesion (Soaked): 15.74
- Angle of Internal Friction (Un soaked): 18
- Angle of Internal Friction (Soaked): 18.91

Marble Content: 40%

- Cohesion (Un soaked): 15.3
- Cohesion (Soaked): 14.74
- Angle of Internal Friction (Un soaked): 19.49
- Angle of Internal Friction (Soaked): 19.9

Marble Content: 50%

- Cohesion (Un soaked): 14.2
- Cohesion (Soaked): 13.6
- Angle of Internal Friction (Un soaked): 20.6
- Angle of Internal Friction (Soaked): 21.2

Cohesion (Unsoaked): As the marble content increases, the cohesion of the soil decreases. This indicates that the stability of the soil decreases with an increase in marble content. Cohesion (Soaked): Similar to the unsoaked cohesion, the soaked cohesion also decreases with an increase in marble content. This suggests that the soil's stability is further compromised when subjected to moisture. The angle of Internal Friction (Unsoaked): The angle of internal friction increases as the marble content increases. This implies that the soil's resistance to shearing forces improves with

the addition of marble. The angle of Internal Friction (Soaked): Similar to the unsoaked condition, the angle of internal friction increases with an increase in marble content, indicating improved stability even when subjected to moisture. Marble Content: Based on the results, it is recommended to increase the marble content to stabilize the collapsible soil. Higher marble content leads to increased resistance to shearing forces and improved stability.

Moisture Management: Since the soaked conditions show reduced cohesion compared to the unsoaked conditions, it is important to manage moisture in the soil. Implementing drainage systems or moisture barriers can help prevent excessive water infiltration and maintain the stability of the soil. Further Testing: Additional direct shear tests should be conducted with varying marble content to establish a more comprehensive understanding of the relationship between marble content and soil stability. This will help in determining the optimal marble content required for maximum stability.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The stabilization of collapsible soil is crucial to mitigate the potential risks associated with its instability. The collapsible soil mixed with the waste marble dust in the percentage from 0%, 10%, 20%, 30%, 40%, and 50%. Based on the study, the following conclusions are drawn:

- The main objective of this research is to investigate the physical properties and the severity of the collapse of the soils in the study area. Based on field and laboratory test results at the investigated depth of the material, the following conclusions are drawn. At the investigated depth the subgrade soil classes fall in A-4, A-6, and A-7-6 according to AASHTO classification, and according to USCS the subgrade soils are classified as ML group of inorganic silt of medium plasticity.
- The maximum dry density values obtained for different percentages of stabilization additives indicate the effectiveness of stabilization techniques in improving soil properties. The results obtained for 0%, 10%, 20%, 30%, 40%, and 50% stabilization indicate maximum dry density values of 1.44, 1.505, 1.707, 1.67, 1.843, and 1.836 respectively.
- The laboratory test results of the soils showed that the specific gravity, liquid limit, and plasticity index ranged from 2.61-2.66, 43.25-27.42%, and 14.56-8.22%% respectively. The collapse potential values computed from the results of odometer tests conducted on samples remolded at in-situ densities and natural moisture contents and at dry densities and optimum moisture contents fall within the ranges of 1.44%-1.836 % and 18.2%-10.4% respectively. From the test results, it has been observed that the collapse potential value can be reduced by compaction.
- The collapse potential value reduced from the range 9.08% to 1.2% in the case of in-situ densities and from the range 1.44% to 1.836% in the case of maximum dry densities when the final load during odometer test changes from the standard load of 200kPa to 105kPa and hence the collapse value can be reduced by minimizing the stress. From the test result, the severity of collapse by the in-situ density and the laboratory maximum density changes from slight to moderate to very slight and this shows the material can be treated by the combination of preventing water contamination with subgrade and compaction technique

to be used in the field to reduce the collapse potential of soil. Also, physical and engineering properties shall be made with comparisons.

5.2. Recommendations

The work presented in this thesis was concerned with the study of the physical properties of the studied area and proposed remedial measures. The inferences drawn from the several tests performed on the soil sample served as the foundation for the recommendations made in this study. The findings show that the proportion of applied compaction effort has a substantial impact on the soil's properties. The guidelines are designed to help engineers and other building industry experts make wise choices regarding the usage of the soil for various uses. It is crucial to remember that these suggestions should be taken into account together with other elements including the project's requirements, the type of soil, and the surrounding environment. The study was carried out and the collapse potential of these soils was evaluated. Additional work is required to better identify the collapsible soils and reduce the collapse potential of the studied area and hence this can be summarized as follows:

In general, a larger compaction effort is advised to produce denser soil based on the findings of the tests performed on the soil sample. To ensure maximum density without too much moisture content, careful calculation of the ideal moisture content for each compaction effort level is advised. Increased compaction efforts can minimize flexibility, improve load-bearing capacity, and lessen the chance of soil swelling and collapsing. A greater effort should be put towards compaction for projects where shear strength is important. Before putting these ideas into practice, it is crucial to take into account other elements including the soil type and the project requirements.

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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

Appendices A

Test Pit Log

 TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B					
Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	
9+500 (RHS)		50	Brownish silty clay		9+700 (LHS)		50	Brownish silty clay		
		100	Light gray sandy gravel (Pumice)				100	Brownish silty clay		
		200	Brownish silty clay				200	Brownish silty clay		
Client:					Consultant:		Contractor:		Project:	
Ethiopia n Roads Authority					JICA Association South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. in JV with Longjian Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km 60 Expressway section Lot-1: Adama - Wolchiche - Km 60 Expressway	
									Title: Test Pit Log	
									Unit: Centimeter	

 TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B					
Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	
7+500 (RHS)		100	Light gray sandy gravel (Pumice)		7+700 (Center)		100	Light gray sandy gravel (Pumice)		
		200	Brownish silty clay	200			Brownish silty clay			
Client:					Consultant:		Contractor:		Project:	
Ethiopian Roads Authority					JICA Associates South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. in JV with Longjian Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km60 Expressway section Lot-1: Adama - Wolchiche - Km 60 Expressway	
									Title: Test Pit Log	
									Unit: Centimeter	

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

					TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B	
Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph		
7+900 (LHS)		100	Light gray sandy gravel (Pumice)		8+100 (Center)		60	Grayish brown silty sand (Pumice)			
		200	Brownish silty clay				200	Brownish silty clay			
Client:					Consultant:		Contractor:		Project:		File: Test Pit Log
Ethiopian Roads Authority					LEA Associates South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Longjian Road & Bridge Co. Ltd.		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Built of Adama - Kun 60 Expressway section 1st-L: Adama - Wolkite - Kun 60 Expressway		Unit: Centimeter

					TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B	
Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph		
8+300 (RHS)			Brownish silty clay		8+500 (LHS)		50	Brownish silty clay			
		100					Light gray sandy gravel (Pumice)				
		200					Brownish silty clay				
Client:					Consultant:		Contractor:		Project:		
Ethiopian Roads Authority					LEA Associates South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Longjian Road & Bridge Co. Ltd.		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Built of Adama - Kun 60 Expressway section 1st-L: Adama - Wolkite - Kun 60 Expressway		
										Unit: Centimeter	

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B				
Station & Coordinate	Graphic Log	Depth	Material Description	Photograph	Station & Coordinate	Graphic Log	Depth	Material Description	Photograph
8+700 (Center)		200	Brownish silty clay		8+900 (RHS)		200	Brownish silty clay	
Client:					Consultant:		Contractor:		Project:
Ethiopian Roads Authority					IJA Associate South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Lorojigan Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km60 Expressway section Lot-1: Adama - Welleschic - Km60 Expressway
									Title: Test Pit Log
									Unit: Centimeter

TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B				
Station & Coordinate	Graphic Log	Depth	Material Description	Photograph	Station & Coordinate	Graphic Log	Depth	Material Description	Photograph
9+100 (LHS)		200	Brownish silty clay		9+300 (Center)		200	Brownish silty clay	
Client:					Consultant:		Contractor:		Project:
Ethiopian Roads Authority					IJA Associate South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Lorojigan Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km60 Expressway section Lot-1: Adama - Welleschic - Km60 Expressway
									Title: Test Pit Log
									Unit: Centimeter

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B					
Station & Coordinate	Graphic Log	Depth	Material Description	Photograph	Station & Coordinate	Graphic Log	Depth	Material Description	Photograph	
9+500 (RHS)		50	Brownish silty clay		9+700 (LHS)		60	Brownish silty clay		
		100	Light gray sandy gravel (Pumice)					Brownish silty clay		
		200	Brownish silty clay							
Client:					Contractor:		Project:		Title: Test Pit Log	
Ethiopian Roads Authority					LEA Associates South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C		JMC Projects (India) Ltd. In JV with Longjian Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km 60 Expressway section 1st-L: Adama - Wolkite - Km 60 Expressway	Unit: Centimeter

 TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B					
Station & Coordinate	Graphic Log	Depth	Material Description	Photograph	Station & Coordinate	Graphic Log	Depth	Material Description	Photograph	
9+900 (Center)		60	Light gray sandy gravel (Pumice)		10+100 (RHS)		60	Brownish silty clay		
		200	Brownish silty clay					Brownish silty clay		
		200	Brownish silty clay							
Client:					Contractor:		Project:		Title: Test Pit Log	
Ethiopian Roads Authority					LEA Associates South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C		JMC Projects (India) Ltd. In JV with Longjian Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km 60 Expressway section 1st-L: Adama - Wolkite - Km 60 Expressway	Unit: Centimeter

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B					
Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	
10+300 (LHS)		60	Light gray sandy gravel (Pumice)		10+500 (Center)		60	Brownish silty clay		
		200	Brownish silty clay				200	Brownish silty clay		
Client:					Consultant:		Contractor:		Project:	
Ethiopian Roads Authority					LIA Associates South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Longjiao Road & Bridge Co. Ltd.		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km 60 Expressway section Lot-1 : Adama - Wolchiche - Km 60 Expressway	
									Title: Test Pit Log	
									Unit: Centimeter	

 TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B					
Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	Station & Coordinate	Graphic Log	Depth	Materials Description	Photograph	
10+700 (RHS)		50	Brownish silty clay		10+900 (LHS)		50	Brownish silty clay		
		100	Light gray sandy gravel (Pumice)				100	Light gray sandy gravel (Pumice)		
		200	Brownish silty clay				200	Brownish silty clay		
Client:					Consultant:		Contractor:		Project:	
Ethiopian Roads Authority					LIA Associates South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Longjiao Road & Bridge Co. Ltd.		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km 60 Expressway section Lot-1 : Adama - Wolchiche - Km 60 Expressway	
									Title: Test Pit Log	
									Unit: Centimeter	

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B							
Station & Coordinate	Graphic Log	Depth	Material's Description	Photograph	Station & Coordinate	Graphic Log	Depth	Material's Description	Photograph			
11+100 (Center)		50	Light gray sandy gravel (Pumice)		11+300 (RHS)		50	Brownish silty clay				
							100	Light gray sandy gravel (Pumice)				
		200	Brownish silty clay				200	Brownish silty clay				
Client:					Consultant:		Contractor:		Project:		Title: Test Pit Log	
Ethiopian Roads Authority					LJA Associates/South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Longjin Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Ken 60 Expressway section Lot-1 : Adama - Welchembe - Ken 60 Expressway		Unit: Centimeter	

					TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION					CORE/GE/RF/084/B	
Station & Coordinate	Graphic Log	Depth	Material Description	Photograph	Station & Coordinate	Graphic Log	Depth	Material Description	Photograph		
11+500 (Center)		50	Light gray sandy gravel (Pumice)		11+700 (LHS)		50	Brownish silty clay			
							100	Light gray sandy gravel (Pumice)			
		200	Brownish silty clay				200	Brownish silty clay			
Client:					Consultant:		Contractor:		Project:		Title: Test Pit Log
Ethiopian Roads Authority					LJA Associates/South Asia Private Limited in Sub Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Longjin Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Ken 60 Expressway section Lot-1 : Adama - Welchembe - Km 60 Expressway		Unit: Centimeter

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

		TEST PIT LOGGING FORMAT FOR SUBGRADE/PAVEMENT INVESTIGATION				CORE/GE/RF/084/B				
Station & Coordinates	Graphic Log	Depth	Materials Description	Photograph	Station & Coordinates	Graphic Log	Depth	Materials Description	Photograph	
11+900 (LHS)		50	Light gray sandy gravel (Pumice)		12+100 (Center)		50	Brownish silty clay		
		100	Light gray sandy gravel (Pumice)				100	Light gray sandy gravel (Pumice)		
		200	Brownish silty clay				200	Brownish silty clay		
Client:					Consultant:		Contractor:		Project:	
Ethiopian Roads Authority					IEA Associate South Asia Private Limited in Sub-Consultancy with United Consulting Engineers P.L.C.		JMC Projects (India) Ltd. In JV with Longjiang Road & Bridge Co. Ltd		Ethiopia - Djibouti Transport Corridor Project Phase-I Design & Build of Adama - Km60 Expressway section Lot-1: Adama - Woldehik - Km 60 Expressway	
									Title: Test Pit Log	
									Unit: Centimeter	

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

Appendices B

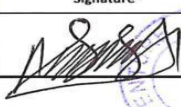
Collapsible Soil Test Result

 ETHIOPIAN ROAD AUTHORITY	CLIENT	 LEA-LASA-UNICONE	CONSULTANT	 JMC - LRBC Joint Venture.	CONTRACTOR
Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway					
SOIL TESTING AND APPROVAL RECORD					
RFI No.				LAB REF. NO.	Format No: 01002/JMC/EHAE/21F/03-R0
SOURCE	Adama to Awash Expressway Road Project			SAMPLEING DATE	25/08/2023
SAMPLING LOCATION	Km.7+700 Center Line			SAMPLE DEPTH (M)	2 m
PURPOSED TO USE	Original Collapseble soil (M.Sc. Research)				
MATERIAL DESCRIPTION:	Brown Silty Soil				

No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS
1	COMPACTION TEST	MDD at 100%	1.440 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557	YES ☐ NO ☐
		OMC	18.2 %		YES ☐ NO ☐
		MDD at 95%	1.368 g/cm ³		YES ☐ NO ☐
2	CBR	CBR at 95% MDD	22.0 %	AASHTO 193/ ASTM D 1883	> 5 YES ☐ NO ☐
		SWELL	0.71 %	< 2 YES ☐ NO ☐	
3	SOIL PLASTICITY	LIQUID LIMIT (LL)	43.3 %	AASHTO T-89/90/ ASTM D 4318	< 60 YES ☐ NO ☐
		PLASTIC LIMIT (PL)	28.7 %	AASHTO T-89/90/ ASTM D 4318	YES ☐ NO ☐
		PLASTICITY INDEX (PI)	14.6 %	AASHTO T-89/90/ ASTM D 4318	< 30 YES ☐ NO ☐

Note: Attach individual test records and data sheet

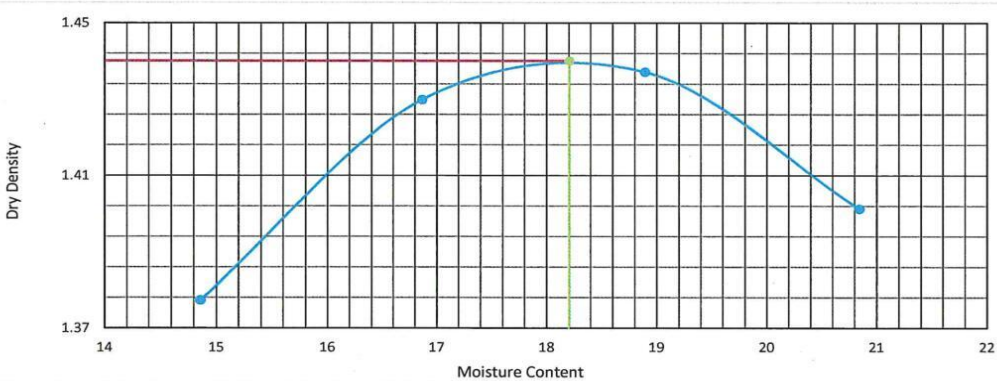
Remarks:

Contractor's Representative			Consultant's Representative		
	Signature	Date		Signature	Date
Material Engineer	 	29/08/23	Material Engineer		

REC-SQP.01-07-01-V0

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY (PHASE-I)		
MAXIMUM DRY DENSITY AND MOISTURE CONTENT (AASHTO T-180) Format No: 01002/JMC/EHAE/21F/03-R0		
RFI No.	Lab Ref No. :	
Source :	Adama to Awash Expressway Road Project	
Location:	Km.7+700 Center Line	
Propose Used	Original Collapseble soil (M.Sc. Research)	
Type of Method:	A	
Material Discription	Brown Silty Soil	
	Depth (M)	2 m
Description	Test I	Test II
	Test III	Test IV
	Test V	
Density Determination		
Water Added %	8%	10%
	12%	14%
Mass of mould + Wet Soil (g)	10070	10270
	10354	10320
Mass of mould, W5 (g)	6522	6522
	6522	6522
Mass of wet soil, W7=W6-W5 (g)	3548	3748
	3832	3798
Volume of mould, V (cc)	2243	2243
	2243	2243
Bulk density, $\gamma_m = [(W7-W6)/V]$ g/cc	1.582	1.671
	1.708	1.693
		NMC
Moisture Content Determination		
Container no	D18	D9
	D12	G2
Mass of container + wet soil, W1 (g)	296.30	293.10
	301.50	274.00
Mass of container + oven dry soil, W2 (g)	261.65	254.70
	258.10	231.35
Mass of Water (g) W3=W1-W2	34.65	38.40
	43.40	42.65
Mass of container, W4 (g)	28.30	27.00
	28.30	26.70
Mass of Dry Soil (g) W5 = W2-W4	233.35	227.70
	229.80	204.65
Moisture Content (%) W6= W3/W5*100	14.85	16.86
	18.89	20.84
		6.84
Dry density, $\gamma_d = \gamma_m / (100 + W6) * 100$ (g/cc)	1.377	1.430
	1.437	1.401
		6.84



The graph plots Dry Density (g/cc) on the y-axis (ranging from 1.37 to 1.45) against Moisture Content (%) on the x-axis (ranging from 14 to 22). A blue curve represents the data points, showing a peak at approximately 18.2% moisture content and a dry density of 1.440 g/cc. A vertical green line marks the peak, and a horizontal red line indicates the Maximum Dry Density (MDD) at 1.440 g/cc.

MDD: 1.440 (gm/cc)	OMC: 18.2 %
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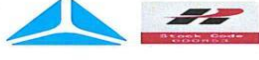

 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer

Verified by
 Consultant's Lab Technician

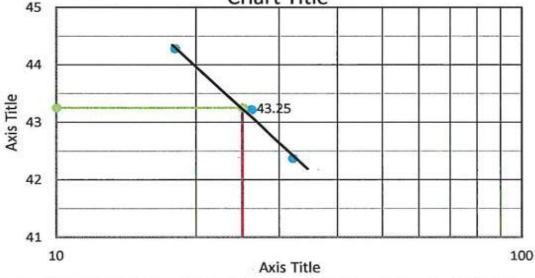
Approved By
 Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC - LRBL Joint Venture.
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT BUILD OF ADAMA-Km 60 EXPRESSWAY)		
(PHASE-I: DESIGN)		
ATTERBERG LIMITS (AASTHO T-89/90)		
Format No: 01002/JMC/EHAE/21F/02-R0		
Test No.	0	
Source :	Adama to Awash Expressway Road Project	
Location:	Km.7+700 Center Line	
Sample Used	Original Collapsible soil (M.Sc. Research)	
Material Description	Brown Silty Soil	
Lab Ref No. :		
Date of Sampling:	25/08/2023	
Date of Testing:	28/08/2023	
Sampled By:	Mihret Rebo	
Tested By:	Mihret Rebo with JMC lab team	

Description	LIQUID LIMIT				PLASTIC LIMIT		
	Test I	Test II	Test III	Test IV	Test I	Test II	Avg.
Number of blows/Penetration (mm)	32	26	18				
Container No	C-12	C-8	C-11		C-20	C-13	
Container + Wet soil, W1 (g)	68.9	58.12	58.78		31.06	31.83	
Container + Dry soil, W2 (g)	55.41	48.22	47.95		29.6	30.18	
Weight of Container (g)	23.57	25.31	23.49		24.41	24.54	
Weight of water, W4= W1-W2 (g)	13.49	9.90	10.83		1.46	1.65	
Weight of oven dry sample, W5=W3 - W1 (g)	31.84	22.91	24.46		5.19	5.64	
Water content percentage, 100x(W4/W5)	42.37	43.21	44.28		28.13	29.26	28.69

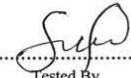
Chart Title



Axis Title

LL	PL	PI
43.25	28.69	14.56

Comments:-


 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer


 Verified by
 Consultant's Lab Technician


 Approved By
 Consultant's Material Engineer

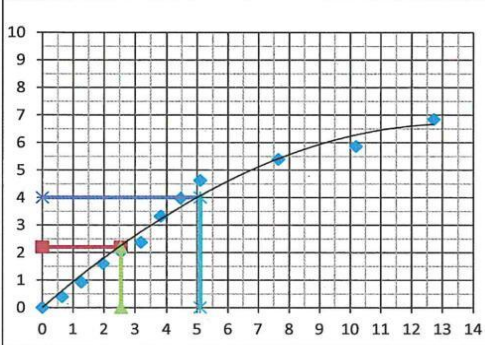
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

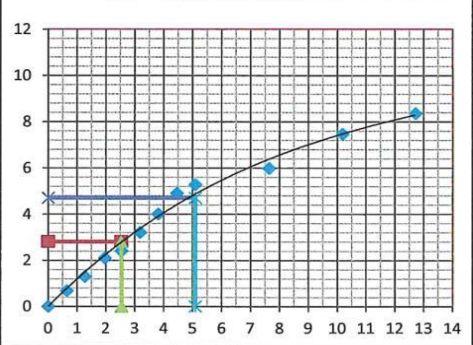
 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC PROJECTS (I) LTD.																																																												
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)																																																														
CALIFORNIA BEARING RATIO TEST (AASHTO T 193) Format No: 01002/JMC/EHAE/21F/04A-R0																																																														
RFI No.	0.000	Lab Ref. No.																																																												
Source :	Adama to Awash Expressway Road Project	Date of Sampling:																																																												
Location:	Km.7+700 Center Line	Date of Soaking:																																																												
Propose Used	Original Collapsible soil (M.Sc. Research)	Date of Testing:																																																												
Material Discription	Brown Silty Soil	Depth (m):																																																												
DENSITY DETERMINATION																																																														
SOAKING CONDITION	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="2">10 Blows</th> <th colspan="2">30 Blows</th> <th colspan="2">65 Blows</th> </tr> <tr> <th>Before</th> <th>After</th> <th>Before</th> <th>After</th> <th>Before</th> <th>After</th> </tr> <tr> <td colspan="6">MOLD NUMBER</td> </tr> <tr> <td colspan="2">M-17</td> <td colspan="2">M-23</td> <td colspan="2">M-25</td> </tr> <tr> <td>WEIGHT OF MOLD</td> <td>7154</td> <td>7154</td> <td>6990</td> <td>6990</td> <td>7174</td> </tr> <tr> <td>WEIGHT OF SOIL + MOLD</td> <td>10468</td> <td>10840</td> <td>10674</td> <td>10850</td> <td>11040</td> </tr> <tr> <td>WEIGHT OF SOIL</td> <td>3314</td> <td>3686</td> <td>3684</td> <td>3860</td> <td>3866</td> </tr> <tr> <td>VOLUME OF MOLD</td> <td>2243</td> <td>2243</td> <td>2243</td> <td>2243</td> <td>2243</td> </tr> <tr> <td>WET DENSITY OF SOIL</td> <td>1.48</td> <td>1.64</td> <td>1.64</td> <td>1.72</td> <td>1.72</td> </tr> <tr> <td>DRY DENSITY OF SOIL</td> <td>1.24</td> <td>1.38</td> <td>1.38</td> <td>1.46</td> <td>1.45</td> </tr> </table>		10 Blows		30 Blows		65 Blows		Before	After	Before	After	Before	After	MOLD NUMBER						M-17		M-23		M-25		WEIGHT OF MOLD	7154	7154	6990	6990	7174	WEIGHT OF SOIL + MOLD	10468	10840	10674	10850	11040	WEIGHT OF SOIL	3314	3686	3684	3860	3866	VOLUME OF MOLD	2243	2243	2243	2243	2243	WET DENSITY OF SOIL	1.48	1.64	1.64	1.72	1.72	DRY DENSITY OF SOIL	1.24	1.38	1.38	1.46	1.45
10 Blows		30 Blows		65 Blows																																																										
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VOLUME OF MOLD	2243	2243	2243	2243	2243																																																									
WET DENSITY OF SOIL	1.48	1.64	1.64	1.72	1.72																																																									
DRY DENSITY OF SOIL	1.24	1.38	1.38	1.46	1.45																																																									
MOISTURE DETERMINATION																																																														
CONTAINER NUMBER	G-1	G-2	G-3	D-28	D-18	D-13																																																								
WET SOIL + CONTAINER (g)	259.40	265.40	274.80	302.70	281.10	261.00																																																								
DRY SOIL + CONTAINER (g)	222.40	227.60	235.50	260.60	240.60	224.00																																																								
WEIGHT OF WATER (g)	37.00	37.80	39.30	42.10	40.50	37.00																																																								
WEIGHT OF CONTAINER (g)	27.20	26.90	27.30	28.70	27.00	27.30																																																								
WEIGHT OF DRY SOIL (g)	195.20	200.70	208.20	231.90	213.60	196.70																																																								
MOISTURE CONTENT (%)	18.95	18.83	18.88	18.15	18.96	18.81																																																								
AVG. MOISTURE CONTENT	18.89		18.52		18.89																																																									
Ring Factor	0.03081																																																													
PENETRATION TEST DATA																																																														
PENETRATION (mm)	Std. Load	Dial reading	Load (kn)	Cor. Load (kn)	Dial reading	Load (kn)	Cor. Load (kn)																																																							
0		0.0	0		0.0	0																																																								
0.64		13.0	0.4		22.0	0.7																																																								
1.27		30.0	0.9		42.0	1.3																																																								
1.96		52.0	1.6		68.0	2.1																																																								
2.54	13.54	66.0	2.0	2.2	78.0	2.4	2.8																																																							
3.18		77.0	2.4		104.0	3.2																																																								
3.81		108.0	3.3		130.0	4.0																																																								
4.45		129.0	4.0		159.0	4.9																																																								
5.08	20.22	150.0	4.6	4.0	171.0	5.3	4.7																																																							
7.62		175.0	5.4		194.0	6.0																																																								
10.16		190.0	5.9		242.0	7.5																																																								
12.7		222.0	6.8		271.0	8.3																																																								
SWELL READING (INITIAL)			3.19				4.19																																																							
SWELL READING (FINAL)			4.80				5.10																																																							
PERCENTAGE SWELL			1.10				0.78																																																							
CBR @ 2.54 mm			16.2				20.7																																																							
CBR @ 5.08 mm			19.8				23.2																																																							
 Tested By Contractor's Lab Technician  Checked By Contractor's Material Engineer 24/08/23 Verified by Consultant's Lab Technician Approved By Consultant's Material Engineer																																																														

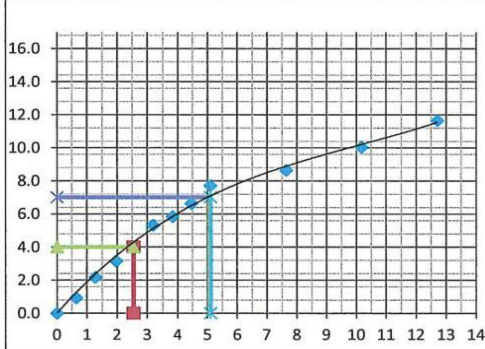
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

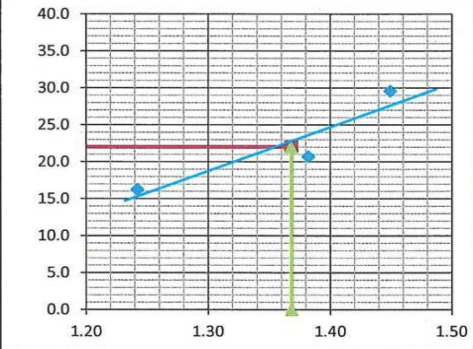
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
Format No: 01002/JMC/EHAE/21F/04B-R0			
RFI No.	0.000	Lab Ref. No.	00/01/1900
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Soaking:	30/08/2023
Propose Used	Original Collapseble soil (M.Sc. Research)	Date of Testing:	03/09/2023
Material Discription	Brown Silty Soil	Depth (m):	2 m

MDD (gm/cc)	1.440	OMC (%)	18.20
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Density @ 95% Compaction (gm/cc)	1.368
CBR @ 95% Compaction (%)	22.0
Swell @ 95% Compaction (%)	0.71

[Signature]

Tested By
Contractor's
Lab Technician

[Signature] 25/08/23

Checked By
Contractor's Material
Engineer

Verified by
Consultant's Lab Technician

Approved By
Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.	
Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway			
SOIL TESTING AND APPROVAL RECORD			
RFI No.		LAB REF. NO.	
SOURCE	Adama to Awash Expressway Road Project	SAMPLEING DATE	25/08/2023
SAMPLING LOCATION	Km.7+700 Center Line	SAMPLE DEPTH (M)	2 m
PURPOSED TO USE	Collapseble soil with 10% marble dust (M.Sc. Research)		
MATERIAL DESCRIPTION:	Brown Silty Soil		

No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS
1	MDD at 100%	1.505 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557		YES ☐ NO ☐
	OMC	16.2 %			YES ☐ NO ☐
	MDD at 95%	1.430 g/cm ³			YES ☐ NO ☐
2	CBR at 95% MDD	25.0 %	AASHTO 193/ ASTM D 1883	> 5	YES ☐ NO ☐
	SWELL	0.54 %		< 2	YES ☐ NO ☐
3	LIQUID LIMIT (LL)	39.4 %	AASHTO T-89/90/ ASTM D 4318	< 60	YES ☐ NO ☐
	PLASTIC LIMIT (PL)	26.2 %	AASHTO T-89/90/ ASTM D 4318		YES ☐ NO ☐
	PLASTICITY INDEX(PI)	13.2 %	AASHTO T-89/90/ ASTM D 4318	< 30	YES ☐ NO ☐

Note: Attach individual test records and data sheet

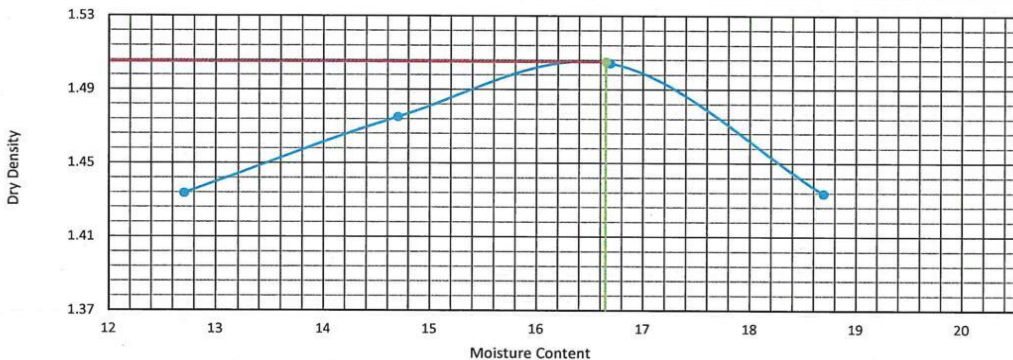
Remarks:

Contractor's Representative		Consultant's Representative	
Signature	Date	Signature	Date
Material Engineer	 20/sep/23	Material Engineer	

REC-SQP.01-07-01-V0

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC - LRBC Joint Venture.
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT OF ADAMA-Km 60 EXPRESSWAY)		
(PHASE-I: DESIGN BUILD)		
MAXIMUM DRY DENSITY AND MOISTURE CONTENT (AASHTO T-180)		
Format No: 01002/JMC/EHAE/21F/03-R0		
Trial No.: Source: Location: Sample Used: Type of Method: Material Description	Adama to Awash Expressway Road Project Km. 7+700 Center Line Collapseable soil with 10% marble dust (M.Sc. Research) A Brown Silty Soil	
	Lab Ref No.: Date of Sampling: Date of Testing: Sampled By: Tested By: Depth (M)	 25/08/2023 01/09/2023 Mihret Rebo Mihret Rebo with JMC lab team 2 m
Description	Test I	Test II
Density Determination		
Water Added %	6%	8%
Mass of mould + Wet Soil (g)	10130	10300
Mass of mould, W5 (g)	6522	6522
Mass of wet soil, W7=W6-W5 (g)	3608	3778
Volume of mould, V (cc)	2243	2243
Bulk density, $\gamma_m = [(W7-W6)/V]$ g/cc	1.609	1.684
Moisture Content Determination		
Container no	G4	D4
Mass of container + wet soil, W1 (g)	282.10	354.70
Mass of container + oven dry soil, W2 (g)	254.35	314.10
Mass of Water (g) W3=W1-W2	27.75	40.60
Mass of container, W4 (g)	27.00	28.10
Mass of Dry Soil (g) W5 = W2-W4	227.35	286.00
Moisture Content (%) $W6 = W3/W5 \times 100$	12.21	14.20
Bulk density, $\gamma_d = \gamma_m / (100 + W6) \times 100$ (g/cc)	1.434	1.475
NMC 6.19		



MDD: 1.505 (gm/cc)	OMC: 16.2 %
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 Tested By
 Contractor's Lab Technician


 Checked By
 Contractor's Material Engineer

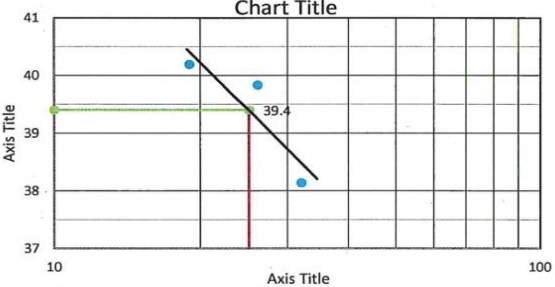

 Verified by
 Consultant's Lab Technician


 Approved By
 Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC - ARBCL Joint Venture.				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)						
ATTERBERG LIMITS (AASTHO T-89/90) Format No: 01002/JMC/EHAE/21F/02-R0						
Test No.	0		Lab Ref No. :	0		
Source :	Adama to Awash Expressway Road Project		Date of Sampling:	25/08/2023		
Location:	Km.7+700 Center Line		Date of Testing:	01/09/2023		
Propose Used	Collapseble soil with 10% marble dust (M.Sc. Research)		Sampled By:	Mihiret Rebo		
Material Discription	Brown Silty Soil		Tested By:	Mihiret Rebo with JMC lab team		
Description	LIQUID LIMIT				PLASTIC LIMIT	
	Test I	Test II	Test III	Test IV	Test I	Test II
Number of blows/Penetration (mm)	32	26	19			
Container No	C-5	C-22	C-71		C-8	C-P
Container + Wet soil, W1 (g)	58.09	60.06	56.6		30.41	29.81
Container + Dry soil, W2 (g)	48.8	50.11	47.3		28.9	28.6
Weight of Container (g)	24.44	25.13	24.16		23.11	23.99
Weight of water, W4= W1-W2 (g)	9.29	9.95	9.30		1.51	1.21
Weight of oven dry sample, W5=W3 - W1 (g)	24.36	24.98	23.14		5.79	4.61
Water content percentage, 100x(W4/W5)	38.14	39.83	40.19		26.08	26.25

Chart Title



LL	PL	PI
39.40	26.16	13.24

Comments:-

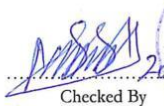
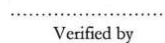
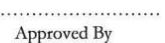

 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer


 Verified by
 Consultant's Lab Technician

Approved By
 Consultant's Material Engineer

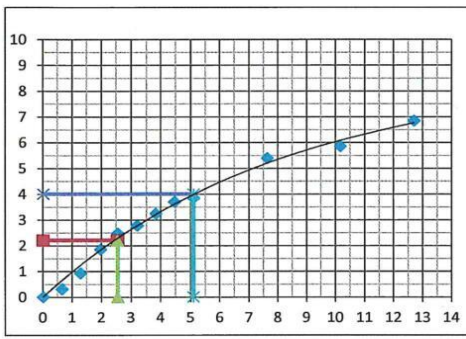
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

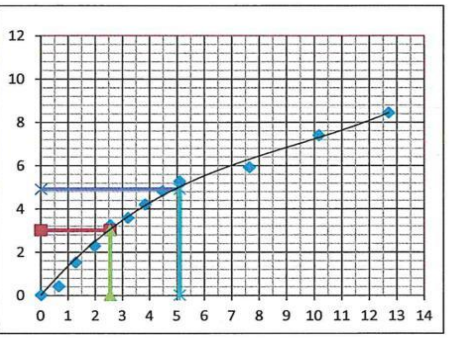
CLIENT  ETHIOPIAN ROAD AUTHORITY		CONSULTANT   LEA-LASA-UNICONE		CONTRACTOR   JMC PROJECTS (I) LTD.							
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)											
CALIFORNIA BEARING RATIO TEST (AASHTO T 193) Format No: 01002/JMC/EHAE/21F/04A-R0											
RFI No.	0.000		Lab Ref. No.	0							
Source :	Adama to Awash Expressway Road Project		Date of Sampling:	25/08/2023							
Location:	Km.7+700 Center Line		Date of Soaking:	02/09/2023							
Propose Used	Collapseble soil with 10% marble dust (M.Sc. Research)		Date of Testing:	06/09/2023							
Material Discription	Brown Silty Soil		Depth (m):	2 m							
DENSITY DETERMINATION											
SOAKING CONDITION	10 Blows		30 Blows		65 Blows						
	Before	After	Before	After	Before After						
MOLD NUMBER	M-16		M-4		M-7						
WEIGHT OF MOLD	7118	7118	7122	7122	7094 7094						
WEIGHT OF SOIL + MOLD	10320	10392	10704	10840	11098 11121						
WEIGHT OF SOIL	3202	3274	3582	3718	4004 4027						
VOLUME OF MOLD	2243	2243	2243	2243	2243 2243						
WET DENSITY OF SOIL	1.43	1.46	1.60	1.66	1.79 1.80						
DRY DENSITY OF SOIL	1.27	1.30	1.42	1.48	1.59 1.60						
MOISTURE DETERMINATION											
CONTAINER NUMBER	A-25	A-17	A-07	A-27	A-8 A-21*						
WET SOIL + CONTAINER (g)	320.40	339.00	303.70	303.30	289.30 291.90						
DRY SOIL + CONTAINER (g)	290.10	305.90	274.50	274.90	261.60 264.80						
WEIGHT OF WATER (g)	30.30	33.10	29.20	28.40	27.70 27.10						
WEIGHT OF CONTAINER (g)	39.53	35.68	36.79	36.59	32.81 39.12						
WEIGHT OF DRY SOIL (g)	250.57	270.22	237.71	238.31	228.79 225.68						
MOISTURE CONTENT (%)	12.09	12.25	12.28	11.92	12.11 12.01						
AVG. MOISTURE CONTENT (%)	12.17		12.10		12.06						
Ring Factor	0.03081										
PENETRATION TEST DATA											
PENETRATION (mm)	Std. Load	Dial reading	Load (kn)	Cor. Load (kn)	Dial reading	Load (kn)	Cor. Load (kn)	Dial reading	Load (kn)	Cor. Load (kn)	
0		0.0	0		0.0	0		0.0	0.0		
0.64		10.0	0.3		13.0	0.4		15.0	0.5		
1.27		30.0	0.9		49.0	1.5		60.0	1.8		
1.96		60.0	1.8		74.0	2.3		120.0	3.7		
2.54	13.54	80.0	2.5	2.2	105.0	3.2	3.0	170.0	5.2	5.2	
3.18		90.0	2.8		116.0	3.6		225.0	6.9		
3.81		105.0	3.2		136.0	4.2		260.0	8.0		
4.45		120.0	3.7		156.0	4.8		283.0	8.7		
5.08	20.22	125.0	3.9	4.0	171.0	5.3	4.9	300.0	9.2	8.9	
7.62		175.0	5.4		192.0	5.9		350.0	10.8		
10.16		190.0	5.9		240.0	7.4		375.0	11.6		
12.7		222.0	6.8		274.0	8.4		390.0	12.0		
SWELL READING (INITIAL)			4.40			4.28			3.62		
SWELL READING (FINAL)			5.25			5.00			3.95		
PERCENTAGE SWELL			0.73			0.62			0.28		
CBR @ 2.54 mm			16.2			22.1			38.4		
CBR @ 5.08 mm			19.8			24.2			44.0		
 Tested By Contractor's Lab Technician  Checked By Contractor's Material Engineer  Verified by Consultant's Lab Technician  Approved By Consultant's Material Engineer											

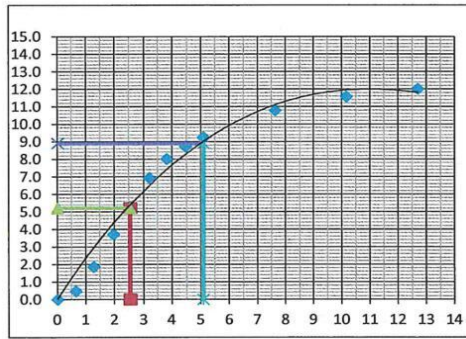
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

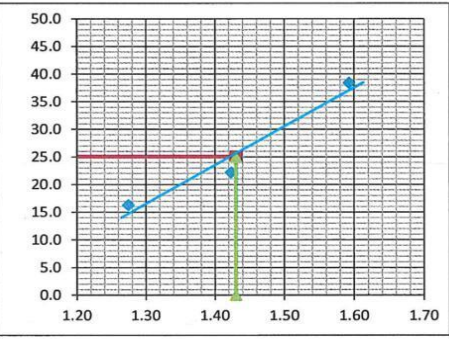
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
Format No: 01002/JMC/EHAE/21F/04B-R0			
RFI No.	0.000	Lab Ref. No.	00/01/1900
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Soaking:	02/09/2023
Propose Used	Collapseble soil with 10% marble dust (M.Sc. Research)	Date of Testing:	06/09/2023
Material Discription	Brown Silty Soil	Depth (m):	2 m

MDD (gm/cc)	1.505	OMC (%)	16.15
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Density @ 95% Compaction (gm/cc)	1.430
CBR @ 95% Compaction (%)	25.0
Swell @ 95% Compaction (%)	0.54

Tested By

Contractor's Lab Technician

Checked By

Contractor's Material Engineer

Verified by

Consultant's Lab Technician

Approved By

Consultant's Material Engineer

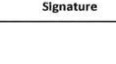
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.	
Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway			
SOIL TESTING AND APPROVAL RECORD			
RFI No.		LAB REF. NO.	
SOURCE	Adama to Awash Expressway Road Project	SAMPLEING DATE	25/10/2023
SAMPLING LOCATION	Km.7+700 Center Line	SAMPLE DEPTH (M)	0.30 to 2 m
PURPOSED TO USE	Collapsible soil with 20% marble dust (M.Sc. Research)		
MATERIAL DESCRIPTION:	Brown Silty Soil		

No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS
1	MDD at 100%	1.732 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557		YES ☐ NO ☐
	OMC	15.1 %			YES ☐ NO ☐
	MDD at 95%	1.645 g/cm ³			YES ☐ NO ☐
2	CBR at 95% MDD	27.0 %	AASHTO 193/ ASTM D 1883	> 5	YES ☐ NO ☐
	SWELL	0.44 %		< 2	YES ☐ NO ☐
3	LIQUID LIMIT (LL)	36.5 %	AASHTO T-89/90/ ASTM D 4318	< 60	YES ☐ NO ☐
	PLASTIC LIMIT (PL)	24.6 %	AASHTO T-89/90/ ASTM D 4318		YES ☐ NO ☐
	PLASTICITY INDEX(PI)	11.8 %	AASHTO T-89/90/ ASTM D 4318	< 30	YES ☐ NO ☐

Note: Attach individual test records and data sheet

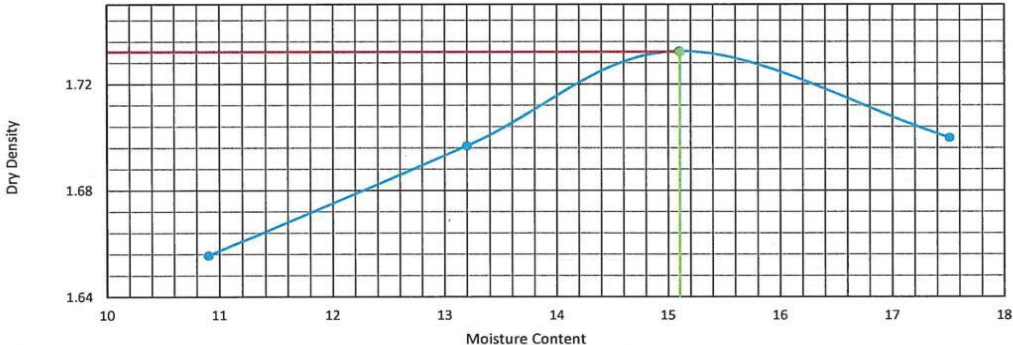
Remarks:

Contractor's Representative		Consultant's Representative	
Signature	Date	Signature	Date
 Material Engineer	20/sep/23	 Material Engineer	

REC-SQP.01-07-01-V0

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBL Joint Venture.			
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT OF ADAMA-Km 60 EXPRESSWAY (PHASE-I: DESIGN BUILD)					
MAXIMUM DRY DENSITY AND MOISTURE CONTENT (AASHTO T-180) Format No: 01002/JMC/EHAE/21F/03-R0					
Sl No.:	Adama to Awash Expressway Road Project		Lab Ref No.:	25/08/2023	
Location:	Km.7+700 Center Line		Date of Sampling:	06/09/2023	
Propose Used	Collapseble soil with 20% marble dust (M.Sc. Research)		Date of Testing:	Mihiret Rebo	
Type of Method:	A		Sampled By:	Mihiret Rebo with JMC lab team	
Material Discription	Brown Silty Soil		Tested By:	0.30 to 2 m	
Description	Test I	Test II	Test III	Test IV	Test V
Density Determination					
Water Added %	6%	8%	10%	12%	
Mass of mould + Wet Soil (g)	10640	10830	10994	11002	
Mass of mould, W5 (g)	6522	6522	6522	6522	
Mass of wet soil, W7=W6-W5 (g)	4118	4308	4472	4480	
Volume of mould, V (cc)	2243	2243	2243	2243	
Moisture density, $y_m = [(W7-W6)/V]$ (g/cc)	1.836	1.921	1.994	1.997	NMC
Moisture Content Determination					
Container no	G1	G2	G3	A4	B6
Mass of container + wet soil, W1 (g)	248.00	260.10	259.40	288.70	279.20
Mass of container + oven dry soil, W2 (g)	226.30	232.90	228.95	251.20	268.00
Mass of Water (g) W3=W1-W2	21.70	27.20	30.45	37.50	11.20
Mass of container, W4 (g)	27.20	26.80	27.20	37.00	37.00
Mass of Dry Soil (g) W5 = W2-W4	199.10	206.10	201.75	214.20	231.00
Moisture Content (%) W6= W3/W5*100	10.90	13.20	15.09	17.51	4.85
Moisture density, $y_s = y_m / (100 + W6) * 100$ (g/cc)	1.656	1.697	1.732	1.700	4.85



MDD: 1.732 (gm/cc)	OMC: 15.1 %
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 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer

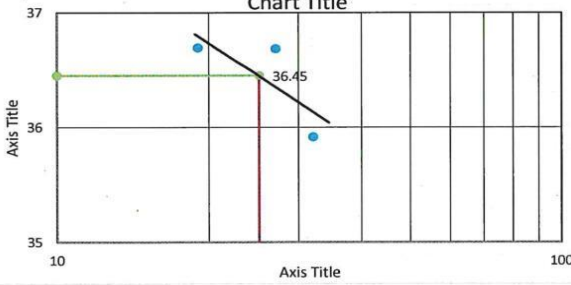

 Verified by
 Consultant's Lab Technician


 Approved By
 Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC - LRBL Joint Venture.
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT BUILD OF ADAMA-Km 60 EXPRESSWAY)		
(PHASE-I: DESIGN)		
ATTEBERG LIMITS (AASHTO T-89/90)		
Format No: 01002/JMC/EHAE/21F/02-R0		
Test No.	0	
Source	Adama to Awash Expressway Road Project	
Location	Km.7+700 Center Line	
Purpose Used	Collapseble soil with 20% marble dust (M.Sc. Research)	
Material Discription	Brown Silty Soil	
	Tested By: Mihiret Rebo with JMC lab team	
Description	LIQUID LIMIT	
	Test I	Test II
	Test III	Test IV
	Test I	Test II
	Avg.	
Number of blows/Penetration (mm)	32	27
Container No	C-17	C-19
Container + Wet soil, W1 (g)	58.38	58.37
Container + Dry soil, W2 (g)	49.8	49.1
Weight of Container (g)	25.91	23.83
Weight of water, W4= W1-W2 (g)	8.58	9.27
Weight of oven dry sample, W5=W3 - W1 (g)	23.89	25.27
Water content percentage, 100x(W4/W5)	35.91	36.68
	36.45	36.69
	30.61	31.15
	29.1	29.9
	22.91	24.87
	1.51	1.25
	6.19	5.03
	24.39	24.85
	24.62	

Chart Title



LL	PL	PI
36.45	24.62	11.83

Comments:-


 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer

Verified by
 Consultant's Lab Technician


 Approved By
 Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	  CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
RFI No.	0.000	Lab Ref. No.	0
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Soaking:	06/09/2023
Propose Used	Collapseble soil with 20% marble dust (M.Sc. Research)	Date of Testing:	10/09/2023
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m
DENSITY DETERMINATION			
SOAKING CONDITION			
	10 Blows		30 Blows
	Before	After	65 Blows
	Before	After	Before
	After	Before	After
MOLD NUMBER	M-3		M-22
WEIGHT OF MOLD	7012	7012	6862
WEIGHT OF SOIL + MOLD	10850	11000	11520
WEIGHT OF SOIL	3838	3988	4658
VOLUME OF MOLD	2243	2243	2243
WET DENSITY OF SOIL	1.71	1.78	2.08
DRY DENSITY OF SOIL	1.44	1.43	1.71
MOISTURE DETERMINATION			
CONTAINER NUMBER	A*21	A-45	A-10
WET SOIL + CONTAINER (g)	268.90	244.20	320.60
DRY SOIL + CONTAINER (g)	232.27	202.63	271.58
WEIGHT OF WATER (g)	36.63	41.57	49.02
WEIGHT OF CONTAINER (g)	39.28	30.28	43.60
WEIGHT OF DRY SOIL (g)	192.99	172.35	227.98
MOISTURE CONTENT (%)	18.98	24.12	21.50
AVG. MOISTURE CONTENT (%)	21.55	21.43	20.07
Ring Factor	0.03081		
PENETRATION TEST DATA			
PENETRATION (mm)	Std. Load	Dial reading	Load (kn)
0		0.0	0
0.64		10.0	0.3
1.27		29.0	0.9
1.96		55.0	1.7
2.54	13.54	80.0	2.5
3.18		95.0	2.9
3.81		120.0	3.7
4.45		155.0	4.8
5.08	20.22	160.0	4.9
5.72		172.0	5.3
6.35		220.0	6.8
6.99		268.0	8.3
SWELL READING (INITIAL)		4.30	4.90
SWELL READING (FINAL)		5.00	5.40
PERCENTAGE SWELL		0.60	0.43
CBR @ 2.54 mm		19.2	23.6
CBR @ 5.08 mm		21.8	31.2


 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer

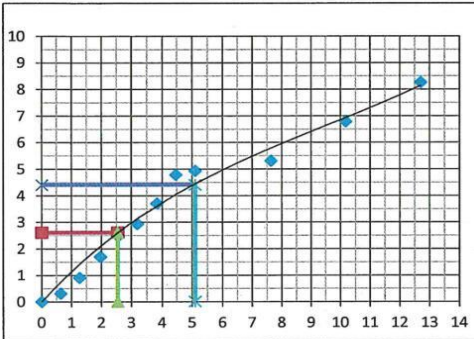

 Verified by
 Consultant's Lab Technician

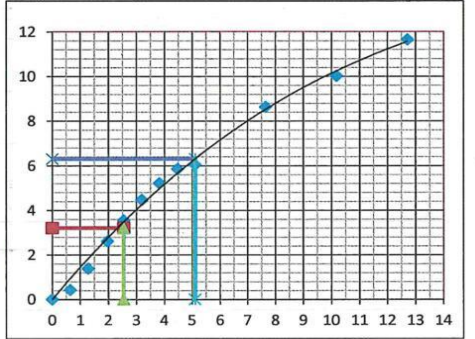

 Approved By
 Consultant's Material Engineer

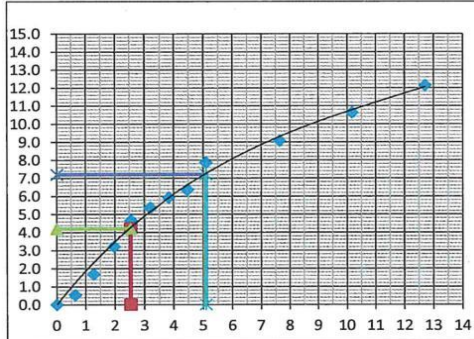
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

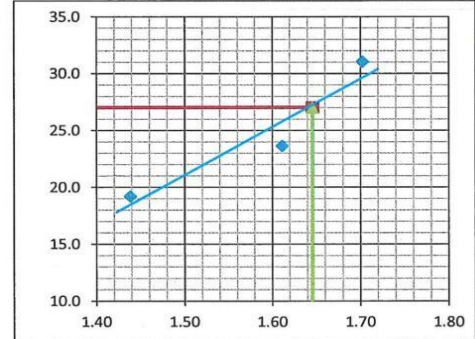
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
Format No: 01002/JMC/EHAE/21F/04B-R0			
RFI No.	0.000	Lab Ref. No.	00/01/1900
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Soaking:	06/09/2023
Propose Used	Collapseble soil with 20% marble dust (M.Sc. Research)	Date of Testing:	10/09/2023
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m

MDD (gm/cc)	1.732	OMC (%)	15.10
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Density @ 95% Compaction (gm/cc)	1.645
CBR @ 95% Compaction (%)	27.0
Swell @ 95% Compaction (%)	0.44

Tested By

Contractor's Lab Technician

Checked By

Contractor's Material Engineer

Verified by

Consultant's Lab Technician

Approved By

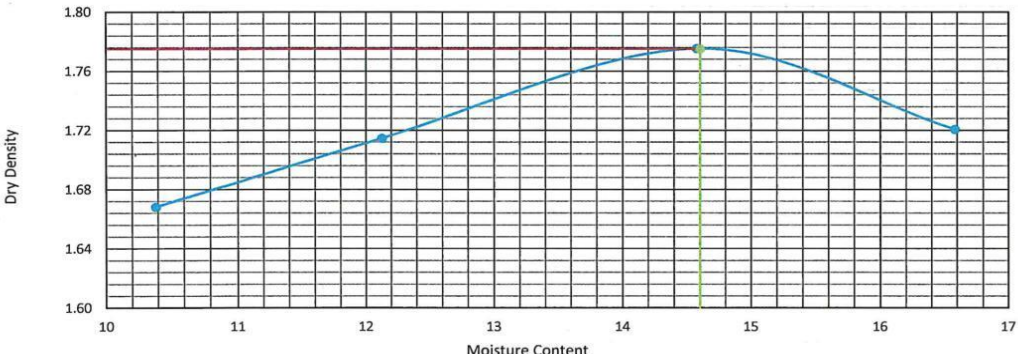
Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.				
Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway						
SOIL TESTING AND APPROVAL RECORD						
RFI No.		LAB REF. NO.				
SOURCE	Adama to Awash Expressway Road Project		SAMPLEING DATE 25/08/2023			
SAMPLING LOCATION	Km.7+700 Center Line		SAMPLE DEPTH (M) 0.30 to 2 m			
PURPOSED TO USE	Collapseble soil with 30% marble dust (M.Sc. Research)					
MATERIAL DESCRIPTION:	Brown Silty Soil					
No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS	
1	COMPACTION TEST	MDD at 100%	1.775 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557	YES ☐ NO ☐	
		OMC	14.6 %		YES ☐ NO ☐	
		MDD at 95%	1.686 g/cm ³		YES ☐ NO ☐	
2	CBR	CBR at 95% MDD	#REF! %	AASHTO 193/ ASTM D 1883	> 5	YES ☐ NO ☐
		SWELL	#REF! %		< 2	YES ☐ NO ☐
3	SOIL PLASTICITY	LIQUID LIMIT (LL)	34.1 %	AASHTO T-89/90/ ASTM D 4318	< 60	YES ☐ NO ☐
		PLASTIC LIMIT (PL)	22.4 %	AASHTO T-89/90/ ASTM D 4318		YES ☐ NO ☐
		PLASTICITY INDEX (PI)	11.7 %	AASHTO T-89/90/ ASTM D 4318	< 30	YES ☐ NO ☐
4	SOIL CHARACTER	SOIL CLASSIFICATION	0.0	AASHTO M 145		YES ☐ NO ☐
5	ORGANIC CONTENT	SOIL CLASSIFICATION	NA	AASHTO T-267-86	< 3	YES ☐ NO ☐
Note: Attach individual test records and data sheet Remarks: 						
Contractor's Representative			Consultant's Representative			
		Signature	Date			
			20/SEP/23			
		Signature	Date			

REC-SQP.01-07-01-V0

CLIENT  ETHIOPIAN ROAD AUTHORITY		CONSULTANT  LEA-LASA-UNICONE		CONTRACTOR  JMC - LRBC Joint Venture.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I:					
DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)					
MAXIMUM DRY DENSITY AND MOISTURE CONTENT (AASHTO T-180) Format No: 01002/JMC/EHAE/21F/03-R0					
Trial No. : _____ Location : Adama to Awash Expressway Road Project Equipment Used : Collapseble soil with 30% marble dust (M.Sc. Research) Type of Method : A Material Description : Brown Silty Soil		Lab Ref No. : _____ Date of Sampling: 25/08/2023 Date of Testing: 10/09/2023 Sampled By: Mihiret Rebo Tested By: Mihiret Rebo with JMC lab team Depth (M) : 0.30 to 2 m			
Description	Test I	Test II	Test III	Test IV	Test V
Density Determination					
Water Added %	6%	8%	10%	12%	
Wet mass of mould + Wet Soil (g)	10652	10834	11084	11021	
Wet mass of mould, W5 (g)	6522	6522	6522	6522	
Wet mass of wet soil, W7=W6-W5 (g)	4130	4312	4562	4499	
Volumetric mass of mould, V (cc)	2243	2243	2243	2243	
Moisture density, $\gamma_m = \frac{[(W7-W6)/V]}{g/cc}$	1.841	1.922	2.034	2.006	NMC
Moisture Content Determination					
Container no	D3	D13	B4	G1	B6
Wet mass of container + wet soil, W1 (g)	326.00	263.00	300.00	275.30	310.40
Wet mass of container + oven dry soil, W2 (g)	298.00	237.50	266.00	240.00	296.70
Mass of Water (g) W3=W1-W2	28.00	25.50	34.00	35.30	13.70
Wet mass of container, W4 (g)	28.30	27.20	32.70	27.10	28.50
Mass of Dry Soil (g) W5 = W2-W4	269.70	210.30	233.30	212.90	268.20
Moisture Content (%) W6= W3/W5*100	10.38	12.13	14.57	16.58	5.11
Moisture density, $\gamma_d = \gamma_m / [(100+W6)*100]$ (g/cc)	1.668	1.715	1.775	1.721	5.11



MDD:	1.775 (gm/cc)	OMC:	14.6 %



Tested By
Contractor's Lab Technician



Checked By
Contractor's Material Engineer

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Verified by
Consultant's Lab Technician

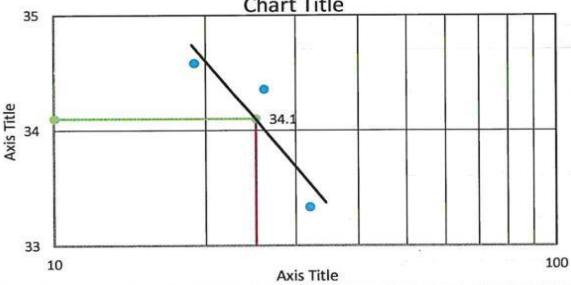
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Approved By
Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

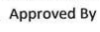
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRCL Joint Venture.					
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN) BUILD OF ADAMA-Km 60 EXPRESSWAY)							
ATTERBERG LIMITS (ASTHO T-89/90) Format No: 01002/JMC/EHAE/21F/02-R0							
Lab No.	0	Lab Ref No. :	0				
Project :	Adama to Awash Expressway Road Project		Date of Sampling:	25/08/2023			
Location:	Km.7+700 Center Line		Date of Testing:	10/09/2023			
Sample Used	Collapseble soil with 30% marble dust (M.Sc. Research)		Sampled By:	Mihiret Rebo			
Material Discription	Brown Silty Soil		Tested By:	Mihiret Rebo with JMC lab team			
Description	LIQUID LIMIT PLASTIC LIMIT						
	Test I	Test II	Test III	Test IV	Test I	Test II	Avg.
Number of blows/Penetration (mm)	32	26	19				
Container No	C-10	C-47	C-3		C46	C-P	
Container + Wet soil, W1 (g)	57.13	58.91	55.93		31.21	31.4	
Container + Dry soil, W2 (g)	49.2	50.4	47.8		29.9	29.9	
Weight of Container (g)	25.41	25.63	24.29		23.97	23.3	22.41
Weight of water, W4= W1-W2 (g)	7.93	8.51	8.13		1.31	1.50	
Weight of oven dry sample, W5=W3 - W1 (g)	23.79	24.77	23.51		5.93	6.60	
Water content percentage, 100x(W4/W5)	33.33	34.36	34.58		22.09	22.73	

Chart Title



LL	PL	PI
34.10	22.41	11.69

Comments:-

 Tested By Contractor's Lab Technician	 Checked By Contractor's Material Engineer	Verified by Consultant's Lab Technician
	 Approved By Consultant's Material Engineer	

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
Format No: 01002/JMC/EHAE/21F/04A-R0			
RFI No.	0.000	Lab Ref. No.	0
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center line	Date of Soaking:	11/09/2023
Propose Used	Collapseble soil with 30% marble dust (M.Sc. Research)	Date of Testing:	15/09/2023
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m
DENSITY DETERMINATION			
SOAKING CONDITION		10 Blows	
		Before	After
MOLD NUMBER		M-9	
WEIGHT OF MOLD	7244	7244	
WEIGHT OF SOIL + MOLD	11150	11196	
WEIGHT OF SOIL	3906	3952	
VOLUME OF MOLD	2243	2243	
WET DENSITY OF SOIL	1.74	1.76	
DRY DENSITY OF SOIL	1.51	1.53	
30 Blows		65 Blows	
		Before	After
MOLD NUMBER		M-18	
WEIGHT OF MOLD	7076	7076	
WEIGHT OF SOIL + MOLD	11444	11478	
WEIGHT OF SOIL	4368	4402	
VOLUME OF MOLD	2243	2243	
WET DENSITY OF SOIL	1.95	1.96	
DRY DENSITY OF SOIL	1.69	1.70	
MOISTURE DETERMINATION		65 Blows	
		Before	After
MOLD NUMBER		M-14	
WEIGHT OF MOLD	7138	7138	
WEIGHT OF SOIL + MOLD	11764	11823	
WEIGHT OF SOIL	4626	4685	
VOLUME OF MOLD	2243	2243	
WET DENSITY OF SOIL	2.06	2.09	
DRY DENSITY OF SOIL	1.79	1.81	
MOISTURE DETERMINATION			
CONTAINER NUMBER	D-9	D-3	D-14
WET SOIL + CONTAINER (g)	340.70	353.10	348.80
DRY SOIL + CONTAINER (g)	299.40	310.40	306.70
WEIGHT OF WATER (g)	41.30	42.70	42.10
WEIGHT OF CONTAINER (g)	27.10	28.20	28.50
WEIGHT OF DRY SOIL (g)	272.30	282.20	278.20
MOISTURE CONTENT (%)	15.17	15.13	15.13
AVG. MOISTURE CONTENT (%)	15.15		15.14
Ring Factor	0.03081		15.19
PENETRATION TEST DATA			
PENETRATION (mm)	Std. Load	Dial reading	Load (kn)
0		0.0	0
0.64		34.0	1.0
1.27		75.0	2.3
1.96		98.0	3.0
2.54	13.54	117.0	3.6
3.18		136.0	4.2
3.81		148.0	4.6
4.45		160.0	4.9
5.08	20.22	170.0	5.2
7.62		200.0	6.2
10.16		220.0	6.8
12.7		230.0	7.1
SWELL READING (INITIAL)		4.63	
SWELL READING (FINAL)		5.11	
PERCENTAGE SWELL		0.41	
CBR @ 2.54 mm		25.8	
CBR @ 5.08 mm		26.7	

Tested By
Contractor's
Lab Technician

Checked By
Contractor's Material Engineer

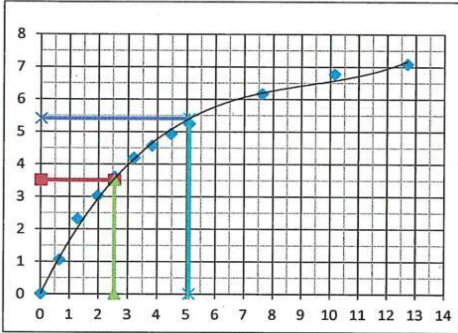
Verified by
Consultant's Lab Technician

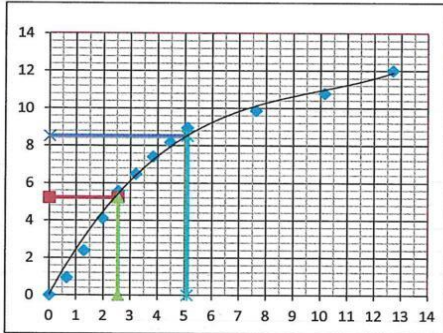
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Consultant's Material Engineer

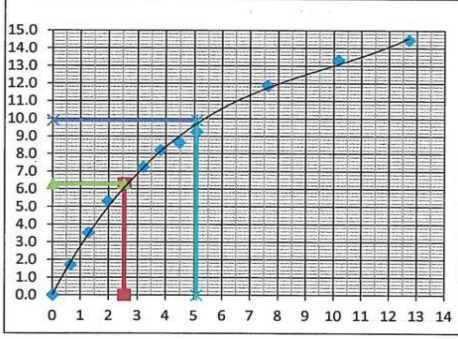
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

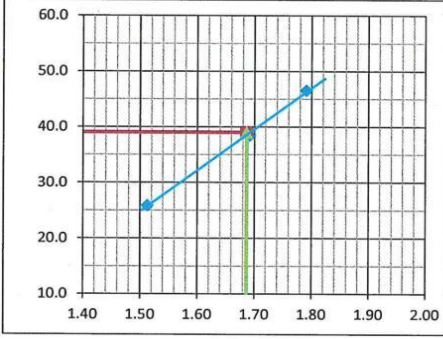
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
RFI No.	0.000	Lab Ref. No.	00/01/1900
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center line	Date of Soaking:	11/09/2023
Propose Used	Collapseble soil with 30% marble dust (M.Sc. Research)	Date of Testing:	15/09/2023
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m

MDD (gm/cc)	1.775	OMC (%)	14.60
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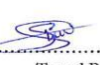
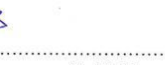








Density @ 95% Compaction (gm/cc)	1.686
CBR @ 95% Compaction (%)	39.0
Swell @ 95% Compaction (%)	0.41

 Tested By Contractor's Lab Technician	 Checked By Contractor's Material Engineer	 Verified by Consultant's Lab Technician	 Approved By Consultant's Material Engineer
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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.	
Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway			
SOIL TESTING AND APPROVAL RECORD			
RFI No.		LAB REF. NO.	
SOURCE	Adama to Awash Expressway Road Project		SAMPLEING DATE 25/08/2023
SAMPLING LOCATION	Km.7+700 Center Line		SAMPLE DEPTH (M) 0.30 to 2 m
PURPOSED TO USE	Collapseble soil with 40% marble dust (M.Sc. Research)		
MATERIAL DESCRIPTION:	Brown Silty Soil		

No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS
1	MDD at 100%	1.843 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557		YES ☐ NO ☐
	OMC	12.2 %			YES ☐ NO ☐
	MDD at 95%	1.751 g/cm ³			YES ☐ NO ☐
2	CBR at 95% MDD	35.5 %	AASHTO 193/ ASTM D 1883	> 5	YES ☐ NO ☐
	SWELL	0.33 %		< 2	YES ☐ NO ☐
3	LIQUID LIMIT (LL)	31.9 %	AASHTO T-89/90/ ASTM D 4318	< 60	YES ☐ NO ☐
	PLASTIC LIMIT (PL)	21.2 %	AASHTO T-89/90/ ASTM D 4318		YES ☐ NO ☐
	PLASTICITY INDEX (PI)	10.7 %	AASHTO T-89/90/ ASTM D 4318	< 30	YES ☐ NO ☐

Note: Attach individual test records and data sheet

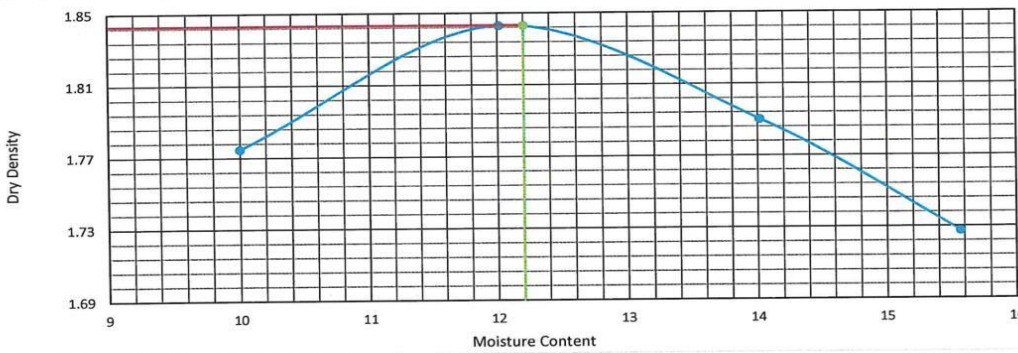
Remarks:

Contractor's Representative			Consultant's Representative		
	Signature	Date		Signature	Date
Material Engineer		20/sep/23	Material Engineer		

REC-SQP.01-07-01-V0

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT BUILD OF ADAMA-Km 60 EXPRESSWAY)		
(PHASE-I: DESIGN)		
MAXIMUM DRY DENSITY AND MOISTURE CONTENT (AASHTO T-180) Format No: 01002/JMC/EHAE/21F/03-R0		
No.:	Adama to Awash Expressway Road Project	
Location:	Km.7+700 Center Line	
Sample Used:	Collapseble soil with 40% marble dust (M.Sc. Research)	
Method:	A	
Material Description:	Brown Silty Soil	
	Test I	Test II
	Test III	Test IV
	Test V	
Density Determination		
Water Added %	4%	6%
Mass of mould + Wet Soil (g)	10900	11152
Mass of mould, W5 (g)	6522	6522
Mass of wet soil, W7=W6-W5 (g)	4378	4630
Volume of mould, V (cc)	2243	2243
Compacted density, $\gamma_m = [(W7-W6)/V]$ g/cc	1.952	2.064
	2.041	1.996
	NMC	
Moisture Content Determination		
Container no	D28	D4
Mass of container + wet soil, W1 (g)	350.00	362.10
Mass of container + oven dry soil, W2 (g)	320.80	326.29
Mass of Water (g) W3=W1-W2	29.20	35.81
Mass of container, W4 (g)	28.70	28.10
Mass of Dry Soil (g) W5 = W2-W4	292.10	298.19
Moisture Content (%) W6= W3/W5*100	10.00	12.01
Compacted density, $\gamma_d = \gamma_m / (100 + W6) * 100$ (g/cc)	1.774	1.843
	1.790	1.728
	6.00	



MDD: 1.843 (gm/cc)	OMC: 12.2 %
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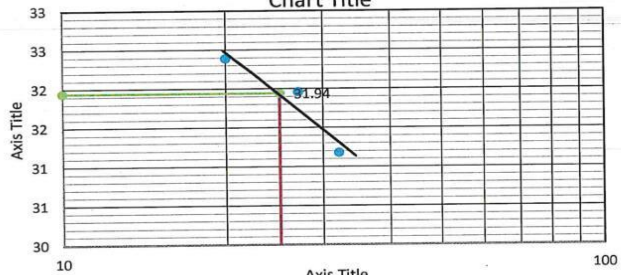
 Tested By Contractor's Lab Technician	 Checked By Contractor's Material Engineer	 Verified by Consultant's Lab Technician	 Approved By Consultant's Material Engineer
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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBC Joint Venture.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
ATTERBERG LIMITS (AASHTO T-89/90) Format No: 01002/JMC/EHAE/21F/02-R0			
Lab No. :	0	Lab Ref No. :	0
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Testing:	12/09/2023
Sample Used	Collapseble soil with 40% marble dust (M.Sc. Research)	Sampled By:	Mihret Rebo
Material Discription	Brown Silty Soil	Tested By:	Mihret Rebo with JMC lab team

Description	LIQUID LIMIT				PLASTIC LIMIT		Avg.
	Test I	Test II	Test III	Test IV	Test I	Test II	
Number of blows/Penetration (mm)	32	27	20				
Container No	C-4	C-16	C-80		C-18	C-15	
Container + Wet soil, W1 (g)	59.24	56.6	57.4		31.04	31.9	
Container + Dry soil, W2 (g)	51.2	49.1	49.3		29.8	30.4	
Weight of Container (g)	25.41	25.63	24.29		23.97	23.3	
Weight of water, W4= W1-W2 (g)	8.04	7.50	8.10		1.24	1.50	
Weight of oven dry sample, W5=W3 - W1 (g)	25.79	23.47	25.01		5.83	7.10	
Water content percentage, 100x(W4/W5)	31.17	31.96	32.39		21.27	21.13	

Chart Title



Axis Title

LL 31.94	PL 21.20	PI 10.74
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Comments:-


 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer

Verified by
 Consultant's Lab Technician

Approved By
 Consultant's Material Engineer

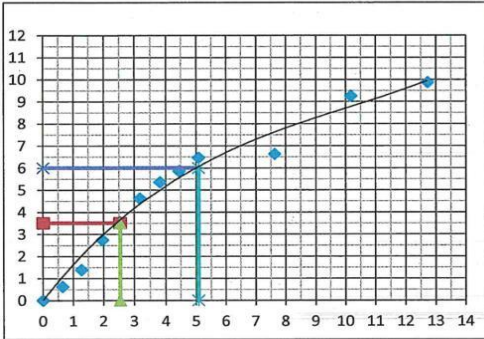
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

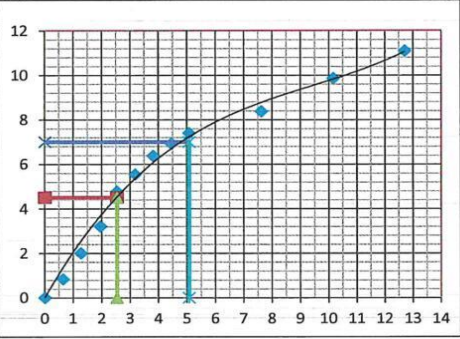
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.								
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I) I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)										
CALIFORNIA BEARING RATIO TEST (AASHTO T 193) Format No: 01002/JMC/EHAE/21F/04A-R0										
RFI No.	0.000	Lab Ref. No.	0							
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023							
Location:	Km.7+700 Center Line	Date of Soaking:	12/09/2023							
Propose Used	Collapseble soil with 40% marble dust (M.Sc. Research)	Date of Testing:	16/09/2023							
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m							
DENSITY DETERMINATION										
SOAKING CONDITION	10 Blows 30 Blows 65 Blows									
	Before	After	Before	After	Before	After				
MOLD NUMBER	M-10		M-8		M-1					
WEIGHT OF MOLD	7148	7148	6612	6612	7000	7000				
WEIGHT OF SOIL + MOLD	11090	11200	11000	11178	11734	11790				
WEIGHT OF SOIL	3942	4052	4388	4566	4734	4790				
VOLUME OF MOLD	2243	2243	2243	2243	2243	2243				
WET DENSITY OF SOIL	1.76	1.81	1.96	2.04	2.11	2.14				
DRY DENSITY OF SOIL	1.57	1.59	1.75	1.80	1.88	1.88				
MOISTURE DETERMINATION										
CONTAINER NUMBER	D-12	A-4	D-14	A3	D-18	B-4				
WET SOIL + CONTAINER (g)	374.60	320.50	337.10	326.40	355.40	275.80				
DRY SOIL + CONTAINER (g)	337.20	287.00	304.00	292.40	320.40	247.10				
WEIGHT OF WATER (g)	37.40	33.50	33.10	34.00	35.00	28.70				
WEIGHT OF CONTAINER (g)	28.30	37.00	28.60	36.90	28.40	32.70				
WEIGHT OF DRY SOIL (g)	308.90	250.00	275.40	255.50	292.00	214.40				
MOISTURE CONTENT (%)	12.11	13.40	12.02	13.31	11.99	13.39				
AVG. MOISTURE CONTENT (%)	12.75		12.66		12.69					
Ring Factor	0.03081									
PENETRATION TEST DATA										
PENETRATION (mm)	Std. Load	Dial reading	Load (kn)	Cor. Load (kn)	Dial reading	Load (kn)	Cor. Load (kn)	Dial reading	Load (kn)	Cor. Load (kn)
0		0.0	0		0.0	0		0.0	0.0	
0.64		20.0	0.6		27.0	0.8		30.0	0.9	
1.27		45.0	1.4		65.0	2.0		78.0	2.4	
1.96		89.0	2.7		104.0	3.2		140.0	4.3	
2.54	13.54	115.0	3.5	3.5	155.0	4.8	4.5	195.0	6.0	6.0
3.18		150.0	4.6		180.0	5.5		250.0	7.7	
3.81		174.0	5.4		207.0	6.4		290.0	8.9	
4.45		190.0	5.9		225.0	6.9		324.0	10.0	
5.08	20.22	210.0	6.5	6.0	240.0	7.4	7.0	350.0	10.8	10.0
7.62		215.0	6.6		272.0	8.4		400.0	12.3	
10.16		300.0	9.2		320.0	9.9		420.0	12.9	
12.7		320.0	9.9		360.0	11.1		460.0	14.2	
SWELL READING (INITIAL)		6.62			4.85			3.50		
SWELL READING (FINAL)		7.10			5.20			3.81		
PERCENTAGE SWELL		0.41			0.30			0.27		
CBR @ 2.54 mm		25.8			33.2			44.3		
CBR @ 5.08 mm		29.7			34.6			49.5		
 Tested By Contractor's Lab Technician  Checked By Contractor's Material Engineer Verified by Consultant's Lab Technician Approved By Consultant's Material Engineer										

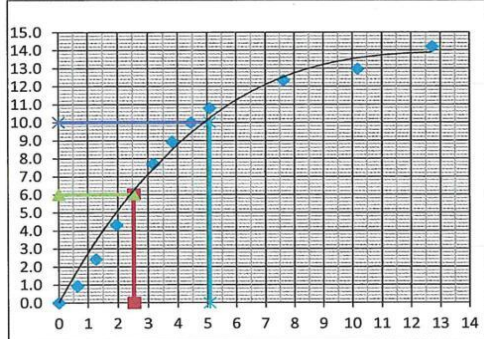
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

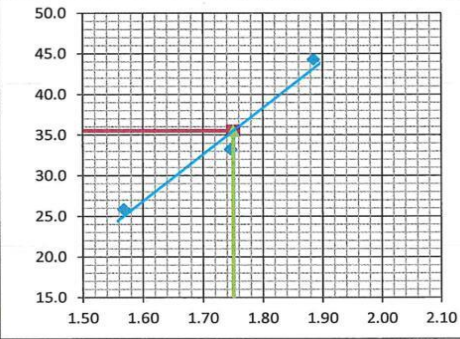
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
Format No: 01002/JMC/EHAE/21F/04B-R0			
RFI No.	0.000	Lab Ref. No.	00/01/1900
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Soaking:	12/09/2023
Propose Used	Collapseble soil with 40% marble dust (M.Sc. Research)	Date of Testing:	16/09/2023
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m

MDD (gm/cc)	1.843	OMC (%)	12.20
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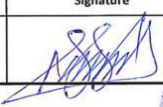




Density @ 95% Compaction (gm/cc)	1.751
CBR @ 95% Compaction (%)	35.5
Swell @ 95% Compaction (%)	0.33

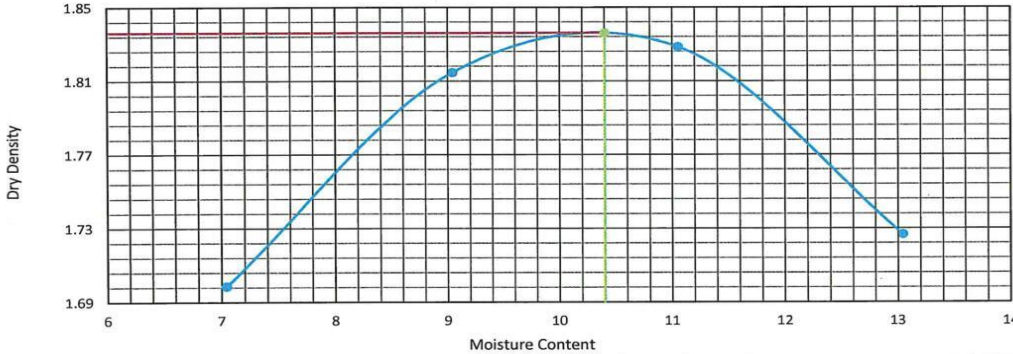
 Tested By Contractor's Lab Technician	 Checked By Contractor's Material Engineer	Verified by Consultant's Lab Technician	Approved By Consultant's Material Engineer
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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.			
Ethiopia - Djibouti Transport Corridor Project Phase I. Design & Build of Adama - Km 60 Expressway					
SOIL TESTING AND APPROVAL RECORD					
RFI No.		LAB REF. NO.			
SOURCE	Adama to Awash Expressway Road Project		SAMPLEING DATE 25/08/2023		
SAMPLING LOCATION	Km.7+700 Center Line		SAMPLE DEPTH (M) 0.30 to 2 m		
PURPOSED TO USE	Collapseble soil with 50% marble dust (M.Sc. Research)				
MATERIAL DESCRIPTION:	Brown Silty Soil				
No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS
1	COMPACTION TEST	MDD at 100%	1.836 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557	YES ☐ NO ☐
		OMC	10.4 %		YES ☐ NO ☐
		MDD at 95%	1.744 g/cm ³		YES ☐ NO ☐
2	CBR	CBR at 95% MDD	31.5 %	AASHTO 193/ ASTM D 1883	> 5 YES ☐ NO ☐
		SWELL	0.41 %		< 2 YES ☐ NO ☐
3	SOIL PLASTICITY	LIQUID LIMIT (LL)	27.4 %	AASHTO T-89/90/ ASTM D 4318	< 60 YES ☐ NO ☐
		PLASTIC LIMIT (PL)	19.2 %	AASHTO T-89/90/ ASTM D 4318	YES ☐ NO ☐
		PLASTICITY INDEX (PI)	8.2 %	AASHTO T-89/90/ ASTM D 4318	< 30 YES ☐ NO ☐
Note: Attach individual test records and data sheet Remarks: 					
Contractor's Representative			Consultant's Representative		
	Signature	Date		Signature	Date
Material Engineer		20/SEP/23	Material Engineer		

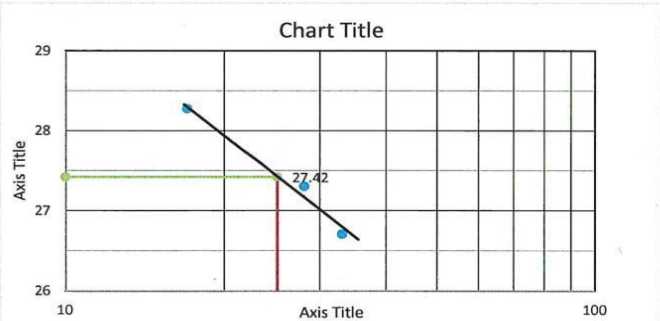
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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC - LRBCL Joint Venture.
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT BUILD OF ADAMA-Km 60 EXPRESSWAY (PHASE-I: DESIGN)		
MAXIMUM DRY DENSITY AND MOISTURE CONTENT (AASHTO T-180) Format No: 01002/JMC/EHAE/21F/03-R0		
1. No. : 2. Source : 3. Location: 4. Purpose Used: 5. Type of Method: 6. Material Description:	Adama to Awash Expressway Road Project Km.7+700 Center Line Collapsible soil with 50% marble dust (M.Sc. Research) A Brown Silty Soil	Lab Ref No. : Date of Sampling: Date of Testing: Sampled By: Tested By: Depth (M)
	Test I Test II Test III Test IV Test V	25/08/2023 13/09/2023 Mihiret Rebo Mihiret Rebo with JMC lab team 0.30 to 2 m
Density Determination		
7. Water Added % 8. Mass of mould + Wet Soil (g) 9. Mass of mould, W5 (g) 10. Mass of wet soil, W7=W6-W5 (g) 11. Volume of mould, V (cc) 12. Bulk density, $\gamma_m = [(W7-W6)/V]$ g/cc	2% 4% 6% 8% 10600 10960 11076 10900 6522 6522 6522 6522 4078 4438 4554 4378 2243 2243 2243 2243 1.818 1.979 2.030 1.952	NMC
Moisture Content Determination		
13. Container no. 14. Mass of container + wet soil, W1 (g) 15. Mass of container + oven dry soil, W2 (g) 16. Mass of Water (g) W3=W1-W2 17. Mass of container, W4 (g) 18. Mass of Dry Soil (g) W5 = W2-W4 19. Moisture Content (%) $W6 = W3/W5 \times 100$ 20. Dry density, $\gamma_d = \gamma_m / (100 + W6) \times 100$ (g/cc)	A16 D9 D12 D18 A45 330.00 373.10 394.70 390.00 236.60 310.71 344.40 358.25 348.28 252.70 19.29 28.70 36.45 41.72 10.90 36.60 27.00 28.30 28.40 36.60 274.11 317.40 329.95 319.88 216.10 7.04 9.04 11.05 13.04 5.04 1.699 1.815 1.828 1.727 5.04	
		
MDD: 1.836 (gm/cc) OMC: 10.4 %		
 Tested By Contractor's Lab Technician	 Checked By Contractor's Material Engineer	 Verified by Consultant's Lab Technician
Approved By Consultant's Material Engineer		

CLIENT  ETHIOPIAN ROAD AUTHORITY		CONSULTANT  LEA-LASA-UNICONE		CONTRACTOR  JMC - IRBCL Joint Venture.				
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY) (PHASE-I:								
ATTERBERG LIMITS (AASHTO T-89/90) Format No: 01002/JMC/EHAE/21F/02-R0								
FI No. 0		Lab Ref No. : 0						
Source : Adama to Awash Expressway Road Project		Date of Sampling: 25/08/2023						
Location: Km.7+700 Center Line		Date of Testing: 13/09/2023						
Propose Used Collapseble soil with 50% marble dust (M.Sc. Research)		Sampled By: Mihiret Rebo						
Material Discription Brown Silty Soil		Tested By: Mihiret Rebo with JMC lab team						
Description		LIQUID LIMIT						
		Test I	Test II	Test III	Test IV	Test I	Test II	Avg.
Number of blows/Penetration (mm) 33		28	17					
Container No c-16		c-18	c-13			C-11	C-10	
Container + Wet soil, W1 (g) 55.25		57.16	52.75			29.17	30.68	
Container + Dry soil, W2 (g) 48.79		50.14	46.53			28.2	29.74	
Weight of Container (g) 24.6		24.43	24.53			23.14	24.85	19.20
Weight of water, W4= W1-W2 (g) 6.46		7.02	6.22			0.97	0.94	
Weight of oven dry sample, W5=W3 - W1 (g) 24.19		25.71	22.00			5.06	4.89	
Water content percentage, 100x(W4/W5) 26.71		27.30	28.27			19.17	19.22	

Chart Title



LL	PL	PI
27.42	19.20	8.22

Comments:-

Tested By

Contractor's Lab Technician

Checked By

Contractor's Material Engineer

Verified by

Consultant's Lab Technician

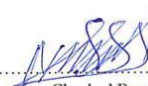
Approved By

Consultant's Material Engineer

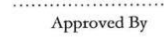
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I) DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193) Format No: 01002/JMC/EHAE/21F/04A-R0			
RFI No.	0.000	Lab Ref. No.	0
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Soaking:	14/09/2023
Propose Used	Collapseble soil with 50% marble dust (M.Sc. Research)	Date of Testing:	18/09/2023
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m
DENSITY DETERMINATION			
SOAKING CONDITION		65 Blows	
	10 Blows	30 Blows	
	Before After	Before After	Before After
MOLD NUMBER	M-15	M-2	M-5
WEIGHT OF MOLD	7240	7240	7118
WEIGHT OF SOIL + MOLD	11022	11152	11809
WEIGHT OF SOIL	3782	3912	4691
VOLUME OF MOLD	2243	2243	2243
WET DENSITY OF SOIL	1.69	1.74	2.09
DRY DENSITY OF SOIL	1.52	1.57	1.88
MOISTURE DETERMINATION			
CONTAINER NUMBER	D-3	D-18	D-9
WET SOIL + CONTAINER (g)	418.00	414.30	310.50
DRY SOIL + CONTAINER (g)	380.20	375.50	282.00
WEIGHT OF WATER (g)	37.80	38.80	28.50
WEIGHT OF CONTAINER (g)	28.20	27.10	27.20
WEIGHT OF DRY SOIL (g)	352.00	348.40	254.80
MOISTURE CONTENT (%)	10.74	11.14	11.19
AVG. MOISTURE CONTENT (%)	10.94	10.60	10.69
Ring Factor	0.03081		
PENETRATION TEST DATA			
PENETRATION (mm)	Std. Load	Dial reading	Load (kn)
0		0.0	0
0.64		13.0	0.4
1.27		30.0	0.9
1.96		52.0	1.6
2.54	13.54	66.0	2.0
3.18		77.0	2.4
3.81		108.0	3.3
4.45		129.0	4.0
5.08	20.22	150.0	4.6
7.62		175.0	5.4
10.16		190.0	5.9
12.7		222.0	6.8
SWELL READING (INITIAL)		4.40	6.35
SWELL READING (FINAL)		5.20	6.74
PERCENTAGE SWELL		0.69	0.34
CBR @ 2.54 mm		16.2	29.5
CBR @ 5.08 mm		19.8	35.6


 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer

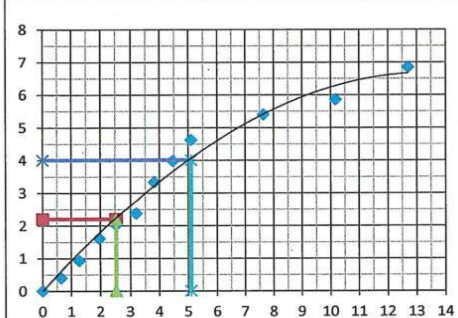
Verified by
 Consultant's Lab Technician

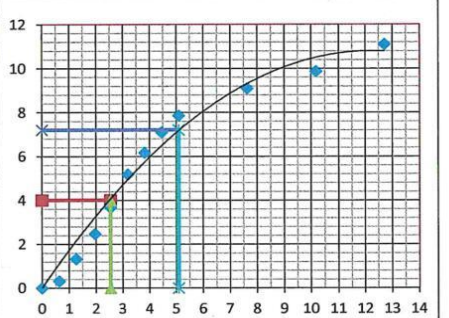

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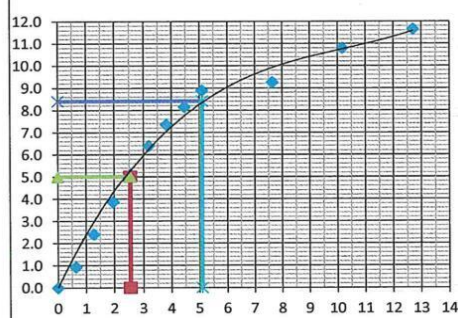
The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

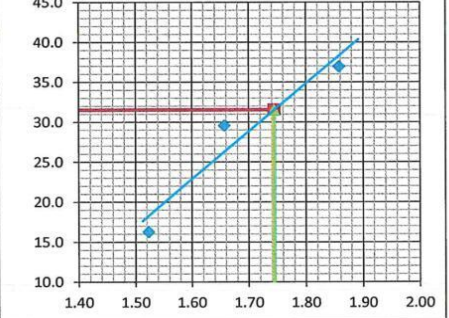
CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC PROJECTS (I) LTD.	
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
CALIFORNIA BEARING RATIO TEST (AASHTO T 193)			
Format No: 01002/JMC/EHAE/21F/04B-R0			
RFI No.	0.000	Lab Ref. No.	00/01/1900
Source :	Adama to Awash Expressway Road Project	Date of Sampling:	25/08/2023
Location:	Km.7+700 Center Line	Date of Soaking:	14/09/2023
Propose Used	Collapseble soil with 50% marble dust (M.Sc. Research)	Date of Testing:	18/09/2023
Material Discription	Brown Silty Soil	Depth (m):	0.30 to 2 m

MDD (gm/cc)	1.836	OMC (%)	10.40
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Density @ 95% Compaction (gm/cc)	1.744
CBR @ 95% Compaction (%)	31.5
Swell @ 95% Compaction (%)	0.41


 Tested By
 Contractor's
 Lab Technician


 Checked By
 Contractor's Material Engineer

Verified by
 Consultant's Lab Technician

Approved By
 Consultant's Material Engineer

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.	
Ethiopia - Djibouti Transport Corridor Project Phase I. & Build of Adama - Km 60 Expressway			
SOIL TESTING AND APPROVAL RECORD			
RFI No.		LAB REF. NO.	
SOURCE	Sendafa Marble factory	SAMPLEING DATE	25/10/2023
SAMPLING LOCATION	Sendafa Marble factory	SAMPLE DEPTH (M)	0.30 to 2 m
PURPOSED TO USE	For Blending with collapsible Soil		
MATERIAL DESCRIPTION:	Marble Dust		

No.	TEST PERFORMED	TEST RESULTS	TEST METHODS	ACCEPTANCE CRITERIA	APPROVAL STATUS
1	MDD at 100%	2.255 g/cm ³	AASHTO T-180 Method D/ ASTM D 1557		YES ☐ NO ☐
	OMC	5.8 %			YES ☐ NO ☐
	MDD at 95%	2.142 g/cm ³			YES ☐ NO ☐
3	LIQUID LIMIT (LL)	NP %	AASHTO T-89/90/ ASTM D 4318	< 60	YES ☐ NO ☐
	PLASTIC LIMIT (PL)	NP %	AASHTO T-89/90/ ASTM D 4318		YES ☐ NO ☐
	PLASTICITY INDEX (PI)	NP %	AASHTO T-89/90/ ASTM D 4318	< 30	YES ☐ NO ☐

Note: Attach individual test records and data sheet

Remarks:

Contractor's Representative			Consultant's Representative		
	Signature	Date		Signature	Date
Material Engineer		20/sep/23	Material Engineer		

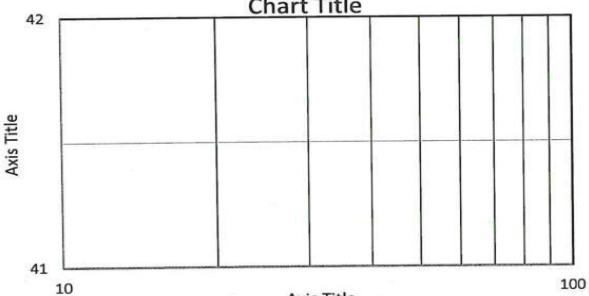


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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CLIENT  ETHIOPIAN ROAD AUTHORITY	CONSULTANT  LEA-LASA-UNICONE	CONTRACTOR  JMC - LRBCL Joint Venture.
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)		
MAXIMUM DRY DENSITY AND MOISTURE CONTENT (AASHTO T-180) Format No: 01002/JMC/EHAE/21F/03-R0		
RFI No.	Lab Ref No. :	
Source :	Date of Sampling: 25/08/2023	
Location:	Date of Testing: 04/08/2023	
Propose Used	Sampled By: Mihiret Rebo	
Type of Method:	Tested By: Mihiret Rebo	
Material Discription	Depth (M) Stock	
Description	Test I	Test II
Density Determination		
Water Added %	2%	4%
Mass of mould + Wet Soil (g)	11550	11750
Mass of mould, W5 (g)	6535	6535
Mass of wet soil, W7=W6-W5 (g)	5015	5215
Volume of mould, V (cc)	2243	2243
Bulk density, $\gamma_m = [(W7-W6)/V]$ g/cc	2.236	2.325
Moisture Content Determination		
Container no	B20	D9
Mass of container + wet soil, W1 (g)	352.00	361.50
Mass of container + oven dry soil, W2 (g)	345.40	348.34
Mass of Water (g) W3=W1-W2	6.60	13.16
Mass of container, W4 (g)	28.30	27.30
Mass of Dry Soil (g) W5 = W2-W4	317.10	321.04
Moisture Content (%) W6= W3/W5*100	2.08	4.10
Dry density, $\gamma_d = \gamma_m / (100 + W6) * 100$ (g/cc)	2.190	2.233
Moisture Content Determination		
Container no	B20	D9
Mass of container + wet soil, W1 (g)	352.00	361.50
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Dry density, $\gamma_d = \gamma_m /$		

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

 CLIENT ETHIOPIAN ROAD AUTHORITY	 CONSULTANT LEA-LASA-UNICONE	 CONTRACTOR JMC - LRBCL Joint Venture.																						
ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)																								
ATTERBERG LIMITS (AASHTO T-89/90) Format No: 01002/JMC/EHAE/21F/02-R0																								
RFI No.	0	Lab Ref No. :	0																					
Source :	Sendafa Marble factory	Date of Sampling:	25/10/2023																					
Location:	Sendafa Marble factory	Date of Testing:	04/08/2023																					
Propose Used	For Blending with Collapsible soil	Sampled By:																						
Material Discription	Marble Dust	Tested By:																						
Description	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="4" style="text-align: center;">LIQUID LIMIT</th> <th colspan="3" style="text-align: center;">PLASTIC LIMIT</th> </tr> <tr> <th>Test I</th> <th>Test II</th> <th>Test III</th> <th>Test IV</th> <th>Test I</th> <th>Test II</th> <th>Avg.</th> </tr> <tr> <td style="text-align: center;">32</td> <td style="text-align: center;">26</td> <td style="text-align: center;">18</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>			LIQUID LIMIT				PLASTIC LIMIT			Test I	Test II	Test III	Test IV	Test I	Test II	Avg.	32	26	18				
LIQUID LIMIT				PLASTIC LIMIT																				
Test I	Test II	Test III	Test IV	Test I	Test II	Avg.																		
32	26	18																						
No of blows/Penetration (mm)																								
Container No																								
Container + Wet soil, W1 (g)																								
Container + Dry soil, W2 (g)																								
Weight of Container (g)																								
Weight of water, W4= W1-W2 (g)																								
Weight of oven dry sample, W5=W3 - W1 (g)																								
Water content percentage, 100x(W4/W5)																								
NP																								
Chart Title 																								
LL	PL	PI																						
NP	NP	NP																						
Comments:-  Tested By Contractor's Lab Technician  Checked By Contractor's Material Engineer Verified by Consultant's Lab Technician Approved By Consultant's Material Engineer																								

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

ETHIOPIA-DJIBOUTI TRANSPORT CORRIDOR PROJECT (PHASE-I: DESIGN BUILD OF ADAMA-Km 60 EXPRESSWAY)			
Client	Ethiopian Roads Authority		
Consultant	LEA Associate South Asia Pvt. Ltd. In association with United Consulting Engineers Plc.		
Contractor	JMC - LRBC Joint Venture.		
<u>SPECIFIC GRAVITY OF SOIL</u> (AASHTO T 100)			
Material Type	Marble	Date of Sampling	25/08/2023
Location	7+700 CL	Date of Testing	29/08/2023
Depth	Stock	Sampled by	Mihiret Rebo
Propose Use	Marble Specific gravity test	Tested by	Mihiret Rebo with JMC lab team
Description of sample		Test 1	Test 2
Water Temperature (°C)		24.9	25
= Weight of flask (g)=W1		115.82	115.82
=Weight of flask + dry soil (g)=W2		150.85	148.5
=Weight of flask+ dry soil + water (g)=W3		378.80	378.2
=Weight of flask + water (g)=W4		355.73	356.40
Specific Gravity of Soil, $(W2-W1)/[(W4-W1)-(W3-W2)]-K$		2.704	2.752
Average			
2.728			
 Tested By Contractor's Lab Technician  Checked By Contractor's Material Engineer Verified by Consultant's Lab Technician Approved By Consultant's Material Engineer			

Appendices-C

Direct Shear Test Result

 **ICT ENGINEERING PRIVATE LIMITED COMPANY**

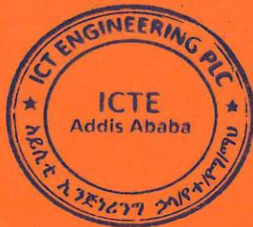
Mehret

MATERIAL TESTING LABORATORY TEST RESULTS

For

Study of Collapsible Soil with Marble Dust

Date: 18 September 2023



We stand Committed to the highest performance standards, fully complying with requirements of the Quality Management System (QMS) and our esteemed Clients.

BUSINESS OFFICE: Sub City : Kirkos, Woreda: 03 House # 524 near Senay Higher Clinic P.O Box: 120563-Gotera Post Office, Addis Ababa, ETHIOPIA Tel.: +251 11 470 2517 E-mail: ictelc@ethionet.et	CENTRAL LABORATORY: Sub City : Kirkos, Woreda: 03 House # 524 near Senay Higher Clinic P.O Box: 120563-Gotera Post Office, Addis Ababa, ETHIOPIA Tel.: +251 911 68 0487 E-mail: n.akhtar1974@yahoo.com
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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project



ICT ENGINEERING PRIVATE LIMITED COMPANY

TEST RESULTS

LAB NUMBER : SCSMD 1290/23
 REQUESTED BY : Mehret
 PROJECT : Study of Collapsible Soil with Marble Dust
 TYPE OF TESTS : Direct Shear Test
 TEST SPECIFIED BY : Mehret
 SAMPLED BY : Mehret
 SUBMITTED BY : Mehret On: 21.08.2023
 REPORTED TO : Mehret On: 18.09.2023

Sl. No.	Sample Station	Sample type	Material Discription	Direct Shear Test	
				Cohesion, C (KPa)	Angle of Internal Friction, ϕ (°)
1	From Adama Awash Road Project	Undisturbed Collapsible Soil	Un Soaked Condition	22.00	13.82
2			Soaked Condition	20.60	14.68
3		Mixed with 10% Marble Dust and 90% Collapsible Soil	Un Soaked Condition	20.20	15.10
4			Soaked Condition	18.84	16.33
5		Mixed with 20% Marble Dust and 80% Collapsible Soil	Un Soaked Condition	18.30	16.91
6			Soaked Condition	17.40	17.43
7		Mixed with 30% Marble Dust and 70% Collapsible Soil	Un Soaked Condition	16.90	18.00
8			Soaked Condition	15.74	18.91
9		Mixed with 40% Marble Dust and 60% Collapsible Soil	Un Soaked Condition	15.30	19.49
10			Soaked Condition	14.74	19.90
11		Mixed with 50% Marble Dust and 50% Collapsible Soil	Un Soaked Condition	14.20	20.60
12			Soaked Condition	13.60	21.20

REMARK :-

Tested by:

Checked by:

Approved by:

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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

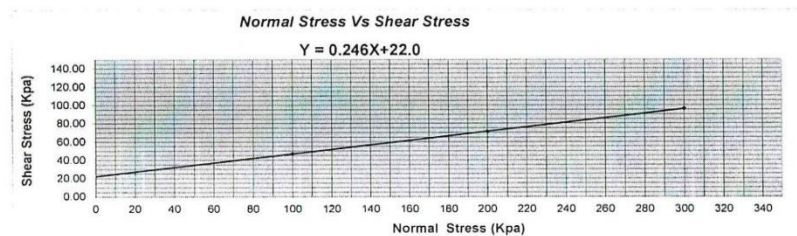


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Un disturbed Collapsible Soil	DATE TESTED	: 05.09.2023
MATERIAL DESCRIPTION	: Un Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	47
200	71
300	96



$C \text{ (kPa)} = 22.0$
 $\phi (^{\circ}) = 13.82$

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



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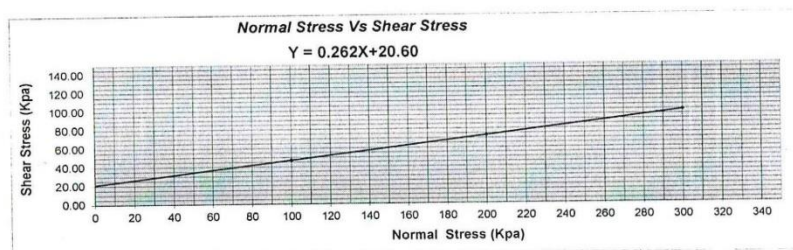


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Un disturbed Collapsible Soil	DATE TESTED	: 05.09.2023
MATERIAL DESCRIPTION	: Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	47
200	73
300	99



C (kPa) = 20.60
 ϕ (°) = 14.68

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



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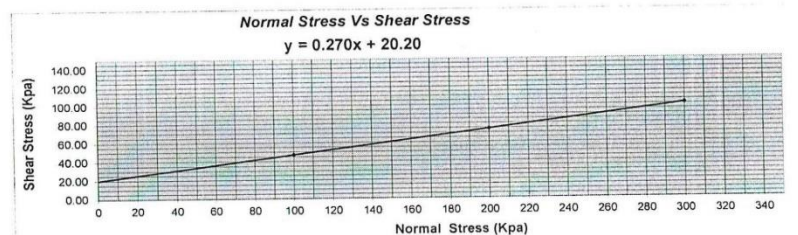


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 10% Marble and 90% Collapsible Soil	DATE TESTED	: 05.09.2023
MATERIAL DESCRIPTION	: Un Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	47
200	74
300	101



C (kPa) = 20.20
 ϕ (°) = 15.10

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

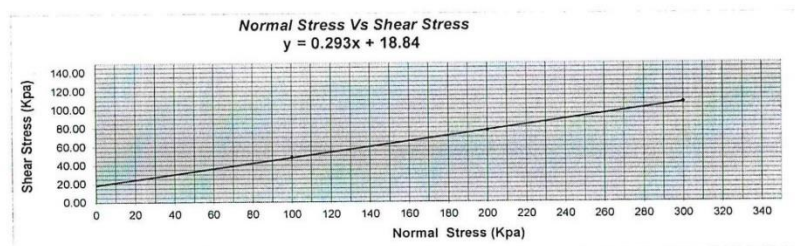


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DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 10% Marble and 90% Collapsible Soil	DATE TESTED	: 05.09.2023
MATERIAL DESCRIPTION	: Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	48
200	77
300	107



C (kPa) = 18.84
 ϕ (°) = 16.33

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



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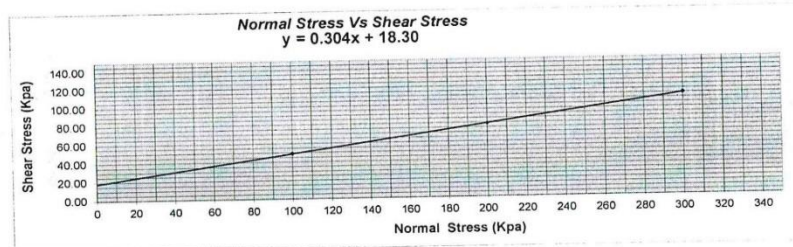


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 20% Marble and 80% Collapsible Soil	DATE TESTED	: 06.09.2023
MATERIAL DESCRIPTION	: Un Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

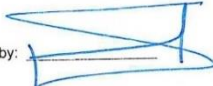
Normal Stress (KPa)	Shear Stress (KPa)
100	49
200	79
300	110



C (kPa) = 18.30
 ϕ (°) = 16.91

REMARK : Test conducted as per BS 1377-1990.

Tested by: 

Checked by: 



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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

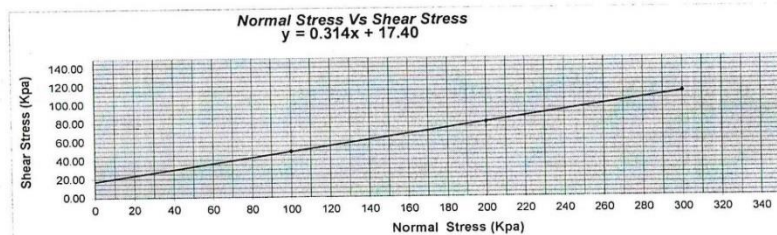


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 20% Marble and 80% Collapsible Soil	DATE TESTED	: 06.09.2023
MATERIAL DESCRIPTION	: Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	49
200	80
300	112



C (kPa) = 17.40
 ϕ (°) = 17.43

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



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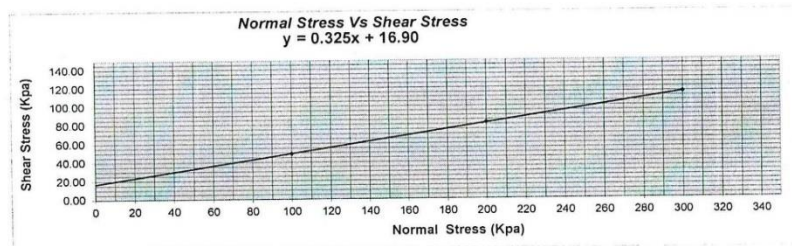


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 30% Marble and 70% Collapsible Soil	DATE TESTED	: 06.09.2023
MATERIAL DESCRIPTION	: Un Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	49
200	82
300	114



C (kPa) = 16.90
 ϕ (°) = 18.00

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



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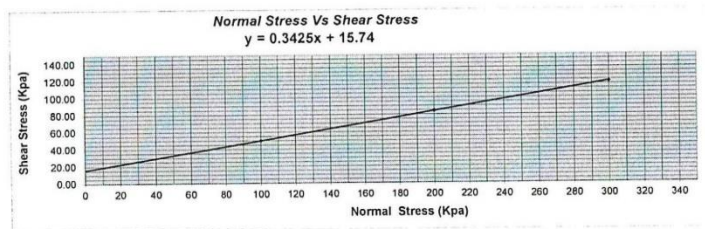


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 30% Marble and 70% Collapsible Soil	DATE TESTED	: 06.09.2023
MATERIAL DESCRIPTION	: Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	50
200	84
300	118



C (kPa) = 15.74
 ϕ (°) = 18.91

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:

Approved by:



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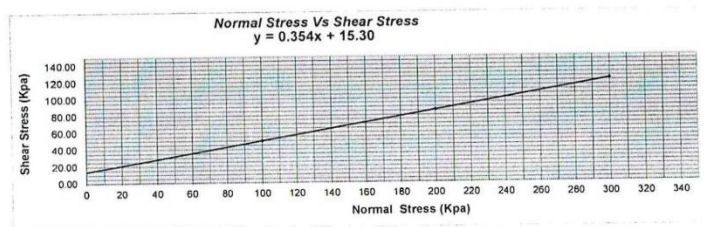


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 40% Marble and 60% Collapsible Soil	DATE TESTED	: 07.09.2023
MATERIAL DESCRIPTION	: Un Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	50
200	86
300	122



C (kPa) = 15.30
 $\phi (^{\circ}) = 19.49$

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



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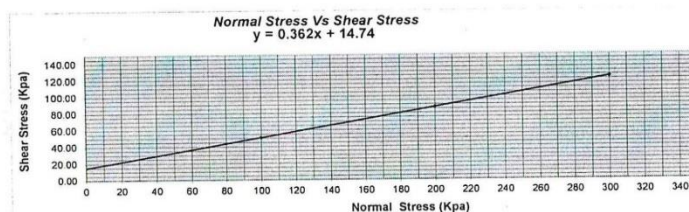


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REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 40% Marble and 60% Collapsible Soil	DATE TESTED	: 07.09.2023
MATERIAL DESCRIPTION	: Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	51
200	87
300	123



C (kPa) = 14.74
 ϕ (°) = 19.90

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:

Approved by:



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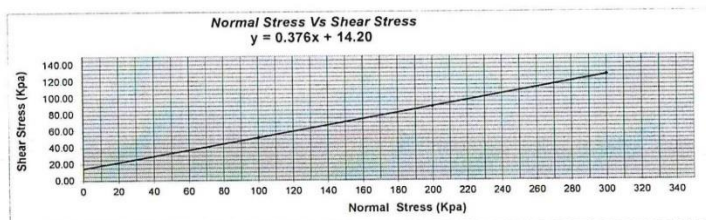


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LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 50% Marble and 50% Collapsible Soil	DATE TESTED	: 07.09.2023
MATERIAL DESCRIPTION	: Un Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	52
200	89
300	127



C (kPa) = 14.20
 ϕ (°) = 20.60

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:

Approved by:



We stand Committed to the highest performance standards, fully complying with requirements of the Quality Management System (QMS) and our esteemed Clients.

BUSINESS OFFICE:

Sub City : Kirkos, Woreda: 03
House # 524 near Senay Higher Clinic
P.O Box: 120563-Gotera Post Office, Addis Ababa, ETHIOPIA
Tel.: +251 11 470 2517 Mob: +251 911 68 04 87
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CENTRAL LABORATORY:

Sub City : Kirkos, Woreda: 03
House # 524 near Senay Higher Clinic
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Mob: +251 911 68 04 87
E-mail: n.akhtar1974@yahoo.com

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

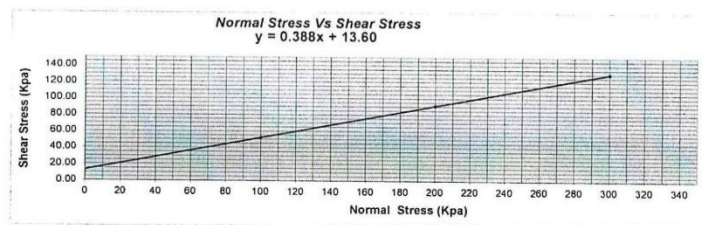


ICT ENGINEERING PRIVATE LIMITED COMPANY

DIRECT SHEAR

LAB. No.	: SCSMD 1290/23	SAMPLED BY	: Mehret
REQUESTED BY	: Mehret	TEST SPECIFIED BY	: Mehret
PROJECT	: Study of Collapsible Soil with Marble Dust	DATE SAMPLED	: —
SAMPLE STATION (km)	: From Adama Awash Road project	DATE SUBMITTED	: 21.08.2023
SAMPLE TYPE	: Mixed with 50% Marble and 50% Collapsible Soil	DATE TESTED	: 07.09.2023
MATERIAL DESCRIPTION	: Soaked Condition	DATE ISSUED	: 18.09.2023
BH. No.	: —	SAMPLE DEPTH (m)	: —

Normal Stress (KPa)	Shear Stress (KPa)
100	52
200	91
300	130



C (kPa) = 13.60
 ϕ (°) = 21.20

REMARK : Test conducted as per BS 1377-1990.

Tested by:

Checked by:



We stand Committed to the highest performance standards, fully complying with requirements of the Quality Management System (QMS) and our esteemed Clients.

BUSINESS OFFICE:

Sub City : Kirkos, Woreda: 03
House # 524 near Senay Higher Clinic
P.O Box: 120563-Gotera Post Office, Addis Ababa, ETHIOPIA
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CENTRAL LABORATORY:

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The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

Appendices-D

Collapse Index Test Result

CORE/GERF/117A

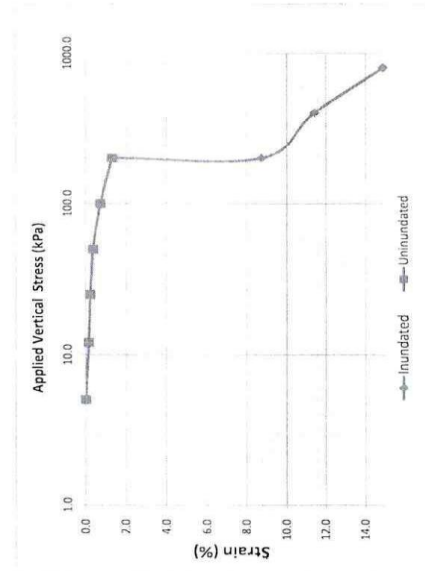
CORE Consulting Engineers P.L.C Materials Testing Laboratory

Measurement of Collapse Index of soils (ASTM 5333-96)

Project: The study of collapsible soil mixed with marble dust
 Client: Mihret Rebo
 Sample of: Marble Dust & Collapsible Soil
 Station: 10% of Marble Dust blended with 90% of Collapsible Soil
 Depth: -----
 Visual Material Description: -----
 Lab No: 2234-23
 Date Tested: 9/8/2023
 Date Reported: 18/08/2023
 Reported to: Mihret Rebo
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.15
Field Moisture Content (%)	---
Final Water content (%)	36.3
Specimen Diameter (mm)	63.5
Initial height h_0 (mm)	25

Sp Gravity	2.469
Initial Void Ratio (e ₀)	1.147
Ring Factor (mm)	0.00254



Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
5	0.00	0.00	0.00	1.15
12.0	14	0.04	0.14	1.14
25.0	22	0.06	0.22	1.14
50.0	36	0.09	0.37	1.14
100.0	72	0.18	0.73	1.13
200.0	128	0.33	1.30	1.12
200	858	2.18	8.72	0.96
400	1125	2.86	11.43	0.90
800	1453	3.72	14.86	0.83

Applied Stress (Kpa)	200
Collapse Index	7.42

Remark:

Reported by:

[Signature]

Laboratory Technician

Checked by:

[Signature]

Laboratory Team Representative

Approved by:

[Signature]

GE Directorate Director



TEL: +251-11-453-4877 FAX: +251-11-350-6833 P.O.Box: 78669/H000

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE/GE/RF/117A

CORE Consulting Engineers P.L.C Materials Testing Laboratory

Measurement of Collapse Index of soils (ASTM 5333-96)

Project : The study of collapsible soil mixed with marble dust

Client : Mihret Rebo

Sample of : Marble Dust & Collapsible Soil

Station : 20% of Marble Dust blended with 80% of Collapsible Soil

Depth : -----

Visual Material Description: -----

Lab No: 2234-23

Date Tested: 9/8/2023

Date Reported: 18/08/2023

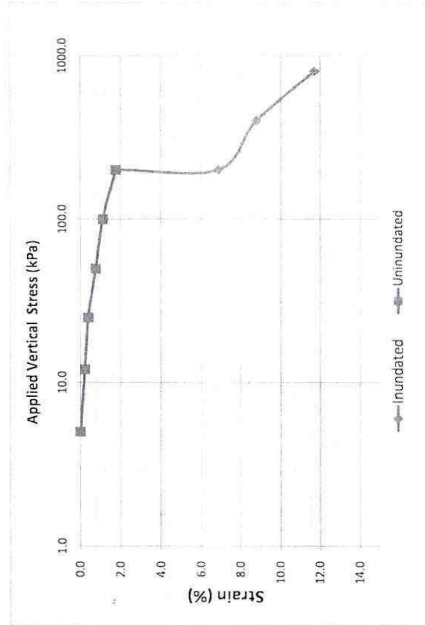
Reported to : Mihret Rebo

Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.15
Field Moisture Content (%)	---
Final Water content (%)	36.3
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp. Gravity	2.437
Initial Void Ratio (e ₀)	1.119
Ring Factor (mm)	0.00254

	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
Before Inundation	5	0.00	0.00	0.00	1.12
	12.0	22	0.06	0.22	1.11
	25.0	38	0.10	0.39	1.11
	50.0	75	0.19	0.76	1.10
	100.0	110	0.28	1.12	1.10
	200.0	173	0.44	1.76	1.08
After Inundation	200	678	1.72	6.89	0.97
	400	865	2.20	8.79	0.93
	800	1152	2.93	11.70	0.87



Applied Stress (Kpa)	200
Collapse Index	5.13

Remark :

Reported by :

[Signature]

Laboratory Technician

Checked by :

[Signature]

Laboratory Team Representative

Approved by :

[Signature]

GE Directorate Director

Tel : +251-11-673-4077

fax : +251-11-376-6033

P.O.Box: 28667/H000

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE/GE/RF/H17A

CORE Consulting Engineers P.L.C Materials Testing Laboratory

Measurement of Collapse Index of soils (ASTM 5333-96)

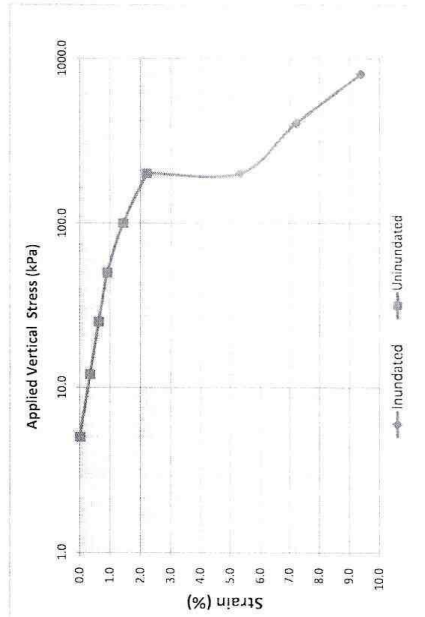
Project : The study of collapsible soil mixed with marble dust
 Client : Mihret Rebo
 Sample of : Marble Dust & Collapsible Soil
 Station : 30% of Marble Dust blended with 70% of Collapsible Soil
 Depth : ----
 Visual Material Description: -----

Lab No: 2234-23
 Date Tested: 9/8/2023
 Date Reported: 18/08/2023
 Reported to : Mihret Rebo
 Reported by : CORE Consulting Engineers P.L.C.

Sp. Gravity	2.456
Initial Void Ratio (e_0)	1.136
Ring Factor (mm)	0.00254

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.15
Field Moisture Content (%)	---
Final Water content (%)	36.3
Specimen Diameter (mm)	63.5
Initial height h_0 (mm)	25

	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
Before Inundation	5	0.00	0.00	0.00	1.14
	12.0	33	0.08	0.34	1.13
	25.0	61	0.15	0.62	1.12
	50.0	90	0.23	0.91	1.12
	100.0	140	0.36	1.42	1.11
	200.0	217	0.55	2.20	1.09
After Inundation	200	523	1.33	5.31	1.02
	400	711	1.81	7.22	0.98
	800	923	2.34	9.38	0.94



Applied Stress (Kpa)	200
Collapse Index	3.11

Remark :

Reported by :
 Laboratory Technician

Checked by :
 Laboratory Team Representative



Approved by :
 GE Directorate Director

Measurement of Collapse Index of soils (ASTM 5333-96)

Project : The study of collapsible soil mixed with marble dust

Client : Mihret Rebo

Sample of: Marble Dust & Collapsible Soil

Station: 40% of Marble Dust blended with 60% of Collapsible Soil

Depth : -----

Visual Material Description:

Lab No: 2234-23

Date Tested: 9/8/2023

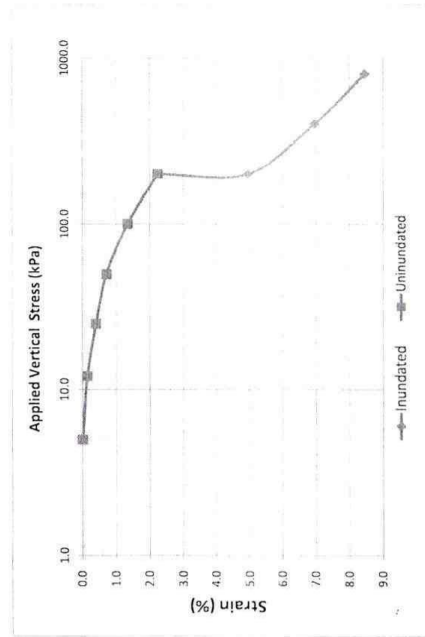
Date Reported: 18/08/2023

Reported to : Mihret Rebo

Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.15
Field Moisture Content (%)	—
Final Water content (%)	36.3
Specimen Diameter (mm)	63.5
Initial height h_0 (mm)	25

Sp.Gravity	2.562
Initial Void Ratio (e_0)	1.228
Ring Factor (mm)	0.00254



	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
Before Inundation	5	0.00	0.00	0.00	1.23
	12.0	14	0.04	0.14	1.22
	25.0	39	0.10	0.40	1.22
	50.0	70	0.18	0.71	1.21
	100.0	132	0.34	1.34	1.20
	200.0	220	0.56	2.24	1.18
After Inundation	200	486	1.23	4.94	1.12
	400	685	1.74	6.96	1.07
	800	832	2.11	8.45	1.04

Remark :

Reported by :

[Signature]

Laboratory Technician

Checked by:



Laboratory Team Representative

Approved by :

for 2

GE Directorate Director

101-8773-033-553-4027

$$-3x = -7 \Rightarrow x = \frac{7}{3}$$

P:040x-2866774000

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE/GE/RF/117A

CORE Consulting Engineers P.L.C/Materials Testing Laboratory

Measurement of Collapse Index of soils (ASTM 5333-96)

Project : The study of collapsible soil mixed with marble dust

Client : Mihret Rebo

Sample of : Marble Dust & Collapsible Soil

Station: 50% of Marble Dust blended with 50% of Collapsible Soil

Depth : -----

Visual Material Description: -----

Lab No: 2234-23

Date Tested: 9/8/2023

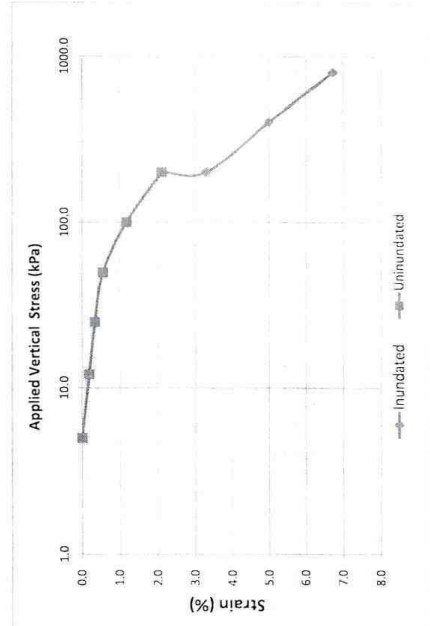
Date Reported: 18/08/2023

Reported to : Mihret Rebo

Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.15
Field Moisture Content (%)	---
Final Water content (%)	36.3
Specimen Diameter (mm)	63.5
Initial height h _c (mm)	25

Sp Gravity	2.583
Initial Void Ratio (e ₀)	1.246
Ring Factor (mm)	0.00254



	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
Before inundation	5	0.00	0.00	0.00	1.25
	12.0	18	0.05	0.18	1.24
	25.0	33	0.08	0.34	1.24
	50.0	54	0.14	0.55	1.23
	100.0	115	0.29	1.17	1.22
	200.0	206	0.52	2.09	1.20
After inundation	200	323	0.82	3.28	1.17
	400	491	1.25	4.99	1.13
	800	661	1.68	6.72	1.10
	Applied Stress (Kpa)	200			
	Collapse Index				1.19

Remark :

Reported by :

[Signature]

Laboratory Technician

Checked by :

[Signature]

Laboratory Team Representative

Approved by :

[Signature]

GE Directorate Director



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Fax: +251 011 370 6033

P.O.Box: 28667/1000

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

Measurement of Collapse Index of soils (ASTM 5333-96)

CORE Consulting Engineers P.L.C/Materials Testing Laboratory

CORE/GE/INF/111/A

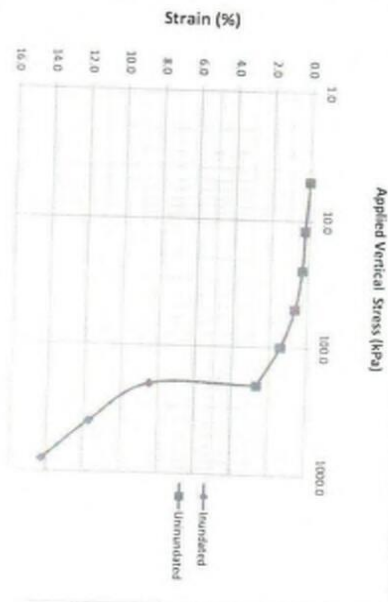
Project : Adama - Km60 Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station : 7+300 LHS
 Depth : 2m
 Visual Material Description :

Lab No: 2101-23
 Date Tested: 7/7/2023
 Date Reported: 14/7/2023
 Reported to: JMC Projects (India) Ltd.
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.34
Field Dry Density (g/cm ³)	1.17
Field Moisture Content (%)	...
Final Water content (%)	32.2
Specimen Diameter (mm)	63.5
Initial height h_0 (mm)	25

Sp Gravity	2.523
Initial Void Ratio (e ₀)	1.156
Ring Factor (mm)	0.00254

	Before Inundation				After Inundation	
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
Before Inundation	5	0.00	0.00	0.00	1.16	
	12.0	20	0.05	0.20	1.15	
	25.0	31	0.08	0.31	1.15	
	50.0	65	0.17	0.66	1.14	
	100.0	139	0.35	1.41	1.13	
	200.0	261	0.66	2.65	1.10	
After Inundation	200	633	2.12	8.46	0.97	
	400	1153	2.93	11.71	0.90	
	800	1402	3.56	14.24	0.85	
				Applied Stress (Kpa)	200	
				Collapse Index	5.81	



Reported by: 
 Laboratory Technician

Checked by: 
 Laboratory Team Representative



Approved by: 
 GE Director/In Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

Measurement of Collapse Index of soils (ASTM 5333-96)

CORE Consulting Engineers P.L.C/Materials Testing Laboratory

CORE/GE/R/11/A

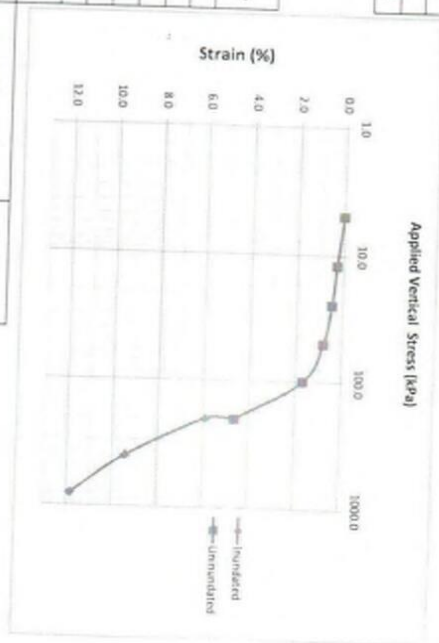
Project : Adama - Km60 Expressway
Client : JMC Projects (India) Ltd
Sample of : Undisturbed Sample of Collapsible Soil
Station : 7+500 RHS
Depth : 1m
Visual Material Description :

Lab No : 2101-23
Date Tested : 6/7/2023
Date Reported : 14/07/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.51
Field Dry Density (g/cm ³)	1.22
Field Moisture Content (%)	---
Final Water content (%)	31.7
Specimen Diameter (mm)	63.5
Initial height h _c (mm)	25

Sp Gravity	2.420
Initial Void Ratio (e _i)	0.984
Ring Factor (mm)	0.00254

	Before Inundation				Applied Stress (Kpa)	Collapse Index
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)		
Before Inundation	5	0.00	0.00	0.00	0.98	200
	12.0	27	0.07	0.27	0.98	
	25.0	46	0.12	0.47	0.97	
	50.0	79	0.20	0.80	0.97	
	100.0	164	0.42	1.67	0.95	
	200.0	495	1.16	4.62	0.89	
	200	580	1.47	5.89	0.87	
After Inundation	400	925	2.35	9.40	0.80	1.27
	800	1163	2.95	11.82	0.75	



Remark :

Reported by :

Laboratory Technician

Checked by :

Laboratory Team Representative

Approved by :

GE Directorate Director



The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/MT/117A

Measurement of Collapse Index of soils (ASTM 533-96)

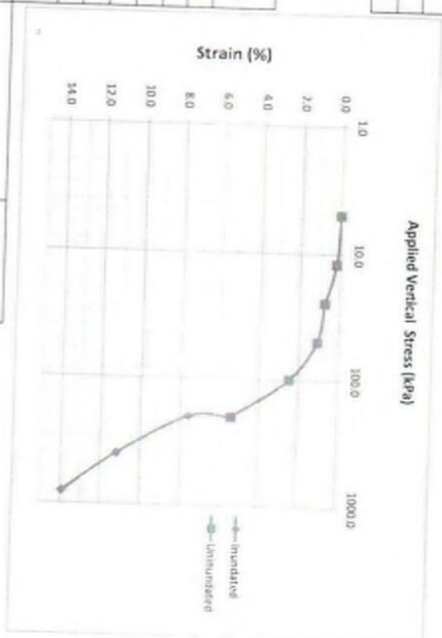
Project : Adama - Kms0 Expressway
Client : JMC Projects (India) Ltd
Sample of : Undisturbed Sample of Collapsible Soil
Station : 7+500 RHS
Depth : 2m
Visual Material Description :

Lab No : 2113-23
Date Tested : 6/7/2023
Date Reported : 14/07/2023
Reported to : JMC Projects (India) Ltd
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.59
Field Dry Density (g/cm ³)	1.31
Field Moisture Content (%)	—
Final Water content (%)	29.7
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.578
Initial Void Ratio (e ₀)	0.968
Ring Factor (mm)	0.00254

Before inundation					After inundation		
Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Strain (%)	Applied Stress (kpa)	
5	0.00	0.00	0.00	0.97	4.0	200	
12.0	18	0.05	0.18	0.96	6.0		
25.0	71	0.18	0.72	0.95	8.0		
50.0	105	0.27	1.07	0.95	10.0		
100.0	243	0.62	2.47	0.92	12.0		
200.0	529	1.34	5.37	0.86	14.0		
200	745	1.89	7.57	0.82			
400	1100	2.79	11.18	0.75		200	
800	1359	3.48	13.91	0.69			
						Collapse Index	2.19



Remark :

Reported by :

[Signature]

Laboratory Technician

Idn-27314311673-0027

Checked by :

[Signature]

Laboratory Team Representative

Idn-27314311673-0033



Approved by :

[Signature]

GE Directorate Director

Idn-27314311673-0033

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GEN/117A

Measurement of Collapse Index of soils (ASTM 5333-96)

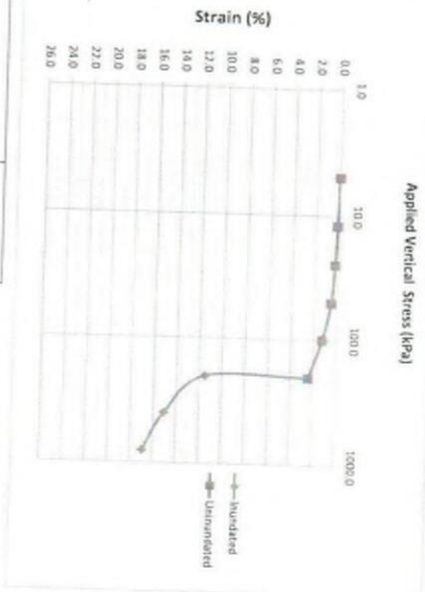
Project : Adama – Km60 Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station : 7+700 CL
 Depth : 2m
 Visual Material Description: ---

Lab No: 2113-23
 Date Tested: 4/7/2023
 Date Reported: 14/07/2023
 Reported to: JMC Projects (India) Ltd.
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.15
Field Moisture Content (%)	---
Final Water content (%)	36.3
Specimen Diameter (mm)	63.5
Initial height h_0 (mm)	25

Sp Gravity	2.459
Initial Void Ratio (e_0)	1.147
Ring Factor (mm)	0.00254

Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
5	0.00	0.00	0.00	1.15	Before Inundation
12.0	13	0.03	0.13	1.14	
25.0	25	0.06	0.25	1.14	
50.0	50	0.13	0.51	1.14	
100.0	120	0.30	1.22	1.12	
200.0	235	0.60	2.39	1.10	
200	1129	2.87	11.47	0.90	After Inundation
400	1463	3.77	15.07	0.82	
800	1863	4.22	16.90	0.78	
				Applied Stress (kpa)	200
				Collapse Index	9.08



Remark :

Reported by: 
 Laboratory Technician

Checked by: 
 Laboratory Team Representative



Approved by: 
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

Measurement of Collapse Index of soils (ASTM 533-96)

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/INT/1117A

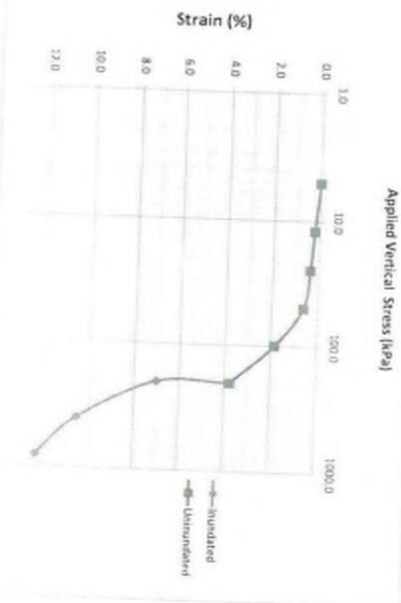
Project: Adama - Kribi Expressway
Client: JMC Projects (India) Ltd
Sample of: Undisturbed Sample of Collapsible Soil
Station: 7+900 LHS
Depth: 2m
Visual Material Description: -----

Lab No: 2101-23
Date Tested: 10/6/2023
Date Reported: 14/07/2023
Reported to: JMC Projects (India) Ltd.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.39
Field Dry Density (g/cm ³)	1.19
Field Moisture Content (%)	---
Final Water content (%)	35.4
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.523
Initial Void Ratio (e ₀)	1.120
Ring Factor (mm)	0.00254

Before Inundation					After Inundation		
Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Strain (%)	Applied Stress (kpa)	Collapse Index
5	0.00	0.00	0.00	1.12			
12.0	21	0.05	0.21	1.12			
25.0	35	0.09	0.36	1.11			
50.0	60	0.15	0.61	1.11			
100.0	180	0.46	1.83	1.08			
200.0	370	0.94	3.76	1.04			
200	691	1.76	7.02	0.97			
400	1035	2.63	10.52	0.90			
800	1211	3.08	12.30	0.86			
					4.0	200	3.26
					6.0		
					8.0		
					10.0		
					12.0		



Remark :

Reported by: 
Laboratory Technician
Tel: +251-011-46144077

Checked by: 
Laboratory Team Representative
Tel: +251-011-46144077



Approved by: 
GE Director/In Director
P.O. Box: 26622/2000

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/PT/117A

Measurement of Collapse Index of soils (ASTM 5333-96)

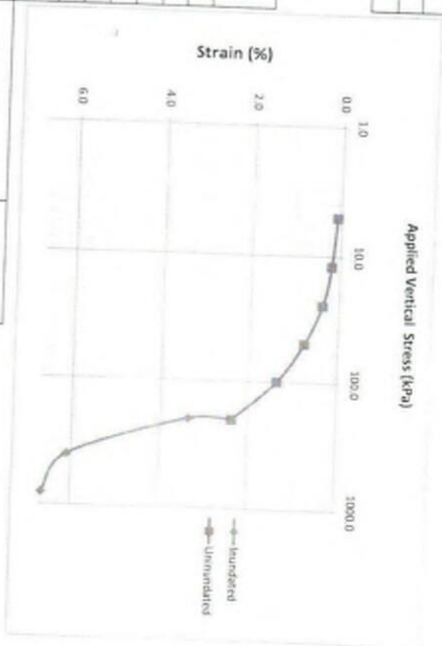
Project : Adama – Km60 Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station : 8+100 CL
 Depth : 1m
 Visual Material Description :

Lab No : 2101-23
 Date Tested : 25/5/2023
 Date Reported : 5/6/2023
 Reported to : JMC Projects (India) Ltd.
 Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.73
Field Dry Density (g/cm ³)	1.48
Field Moisture Content (%)	---
Final Water content (%)	43.54
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp.Gravity	2.432
Initial Void Ratio (e ₀)	0.643
Ring Factor (mm)	0.00234

	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Applied Stress (Kpa)	Collapse Index
Before Inundation	5	8	0.02	0.08	0.64	200	1.00
	12.0	19	0.05	0.19	0.64		
	25.0	37	0.09	0.38	0.64		
	50.0	75	0.19	0.76	0.63		
	100.0	135	0.34	1.37	0.62		
	200.0	232	0.59	2.36	0.60		
	200	330	0.84	3.35	0.59		
After Inundation	400	600	1.52	6.10	0.54	200	1.00
	800	655	1.66	6.65	0.53		



Remark :

Reported by :
 Laboratory Technician

Checked by :
 Laboratory Team Representative



Approved by :
 GE Directorate Director

P.O.Box 78627/Thiara

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Materials Testing Laboratory

CORE/GE/JRF/111/A

Measurement of Collapse Index of soils (ASTM 5333-96)

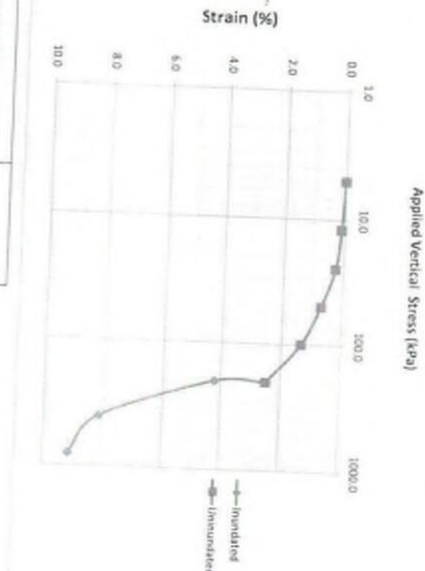
Project : Adama - Km60 Expressway
Client : JMC Projects (India) Ltd.
Sample of : Undisturbed Sample of Collapsible Soil
Station: 8+100 CL
Depth : 2m
Visual Material Description:

Lab No: 2101-23
Date Tested: 25/5/2023
Date Reported: 5/6/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.58
Field Dry Density (g/cm ³)	1.29
Field Moisture Content (%)	---
Final Water content (%)	31.59
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	29

Sp Gravity	2.478
Initial Void Ratio (e ₀)	0.921
Ring Factor (mm)	0.00254

Applied Vertical Stress (kpa)	Before Inundation		After Inundation	
	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
5	0.00	0.00	0.00	0.92
12.0	10	0.03	0.10	0.92
25.0	25	0.06	0.25	0.92
50.0	69	0.18	0.70	0.91
100.0	131	0.33	1.33	0.90
200.0	245	0.62	2.49	0.87
200	415	1.05	4.22	0.84
400	800	2.03	8.13	0.76
800	900	2.29	9.14	0.75
				Applied Stress (Kpa)
				200
				Collapse Potential
				1.73



Remark :

Reported by :
 Laboratory Technician

Checked by :
 Laboratory Team Representative



Approved by :
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/CI/111/A

Measurement of Collapse Index of soils (ASTM 533-96)

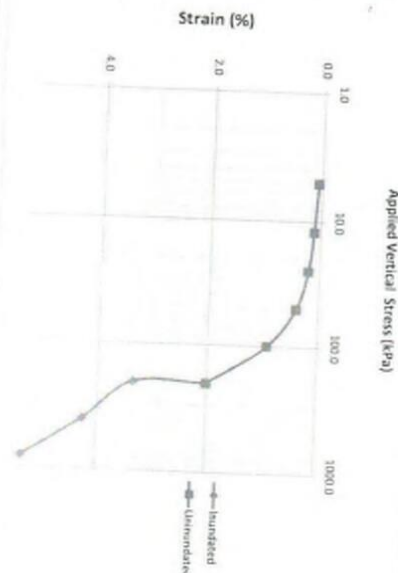
Project: Adama - Km60 Expressway
Client: JMC Projects (India) Ltd.
Sample of: Undisturbed Sample of Collapsible Soil
Station: 8+300 RHS
Depth: 2m
Visual Material Description:

Lab No: 2101-23
Date Tested: 18/5/2023
Date Reported: 5/6/2023
Reported to: JMC Projects (India) Ltd.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.89
Field Dry Density (g/cm ³)	1.38
Field Moisture Content (%)	26.8
Final Water Content (%)	30.9
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.614
Initial Void Ratio (e _i)	0.894
Ring Factor (mm)	0.00254

	Before Inundation			After Inundation		
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
Before Inundation	5	6	0.02	0.06	0.89	
	12.0	12	0.03	0.12	0.89	
	25.0	20	0.05	0.20	0.89	
	50.0	40	0.10	0.41	0.89	
	100.0	91	0.23	0.92	0.88	
	200.0	198	0.50	2.01	0.86	
After Inundation	200	330	0.84	3.35	0.83	
	400	420	1.07	4.27	0.81	Applied Stress (kpa)
	800	530	1.35	5.38	0.79	Collapse Potential



Remark:

Reported by:

[Signature]

Laboratory Technician

Checked by:

[Signature]

Laboratory Team Representative

140-2101-011401-1401-017

140-2101-011401-1401-013



Approved by:

[Signature]

GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/11/1A

Measurement of Collapse Index of soils (ASTM 5333-96)

Project : Adama – Km60 Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station : 8+500 LHS
 Depth : 1m
 Visual Material Description :

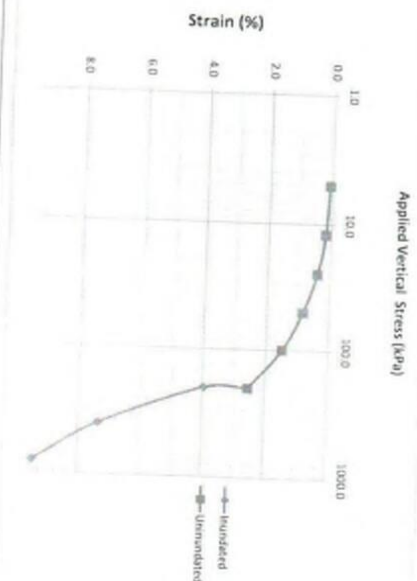
Lab No : 2101-23
 Date Tested : 23/5/2023
 Date Reported : 5/6/2023
 Reported to : JMC Projects (India) Ltd.
 Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.09
Field Dry Density (g/cm ³)	0.89
Field Moisture Content (%)	---
Final Water content (%)	51.32
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.385
Initial Void Ratio (e ₀)	1.680
Ring Factor (mm)	0.00254

Before Inundation					After Inundation	
Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Strain (%)	
5	7	0.02	0.07	1.68		
12.0	17	0.04	0.17	1.68		
25.0	40	0.10	0.41	1.67		
50.0	81	0.21	0.82	1.66		
100.0	144	0.37	1.46	1.64		
200.0	250	0.64	2.54	1.61		
200	390	0.99	3.96	1.57		
400	725	1.84	7.37	1.48		
800	930	2.36	9.45	1.43		

Applied Stress (kpa)	Collapse Potential
200	1.42



Remark :

Reported by :
 Laboratory Technician

Checked by :
 Laboratory Team Representative



Approved by :
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Materials Testing Laboratory

CORE/CL/MT/11/A

Measurement of Collapse Index of soils (ASTM 5333-96)

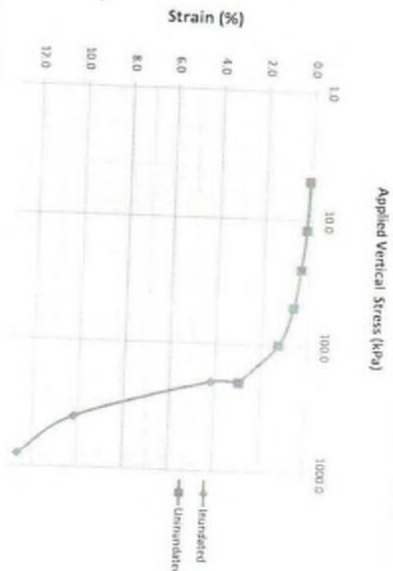
Project : Adama - Km60 Expressway
Client : JMC Projects (India) Ltd.
Sample of : Undisturbed Sample of Collapsible Soil
Station : 8+500 LHS
Depth : 2m
Visual Material Description :

Lab No : 2101-23
Date Tested : 23/5/2023
Date Reported : 5/6/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.09
Field Moisture Content (%)	---
Final Water content (%)	34.09
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.295
Initial Void Ratio (e ₀)	1.106
Ring Factor (mm)	0.00254

Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Before Inundation		After Inundation	
			Strain (%)	Void Ratio	Applied Stress (kpa)	Collapse Potential
5	8	0.02	0.08	1.10	200	1.22
12.0	16	0.04	0.16	1.10		
25.0	35	0.09	0.36	1.10		
50.0	62	0.16	0.63	1.09		
100.0	123	0.31	1.25	1.08		
200.0	290	0.74	2.95	1.04		
	410	1.04	4.17	1.02		
	998	2.54	10.15	0.89		
	1241	3.15	12.61	0.84		



Remark :

Reported by :
Laboratory Technician

Checked by :
Laboratory Team Representative



Approved by :
GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/IR/1117A

Measurement of Collapse Index of soils (ASTM 5333-96)

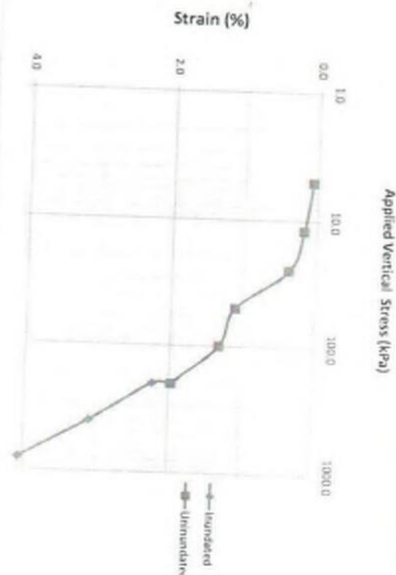
Project: Adama - Km60 Expressway
Client: JMC Projects (India) Ltd.
Sample of: Undisturbed Sample of Collapsible Soil
Station: 8+700 CL
Depth: 2m
Visual Material Description: -----

Lab No: 2101-23
Date Tested: 28/5/2023
Date Reported: 5/6/2023
Reported to: JMC Projects (India) Ltd.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.17
Field Dry Density (g/cm ³)	0.96
Field Moisture Content (%)	---
Final Water content (%)	38.6
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.299
Initial Void Ratio (e ₀)	1.346
Ring Factor (mm)	0.00254

	Before Inundation		After Inundation	
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)
Before Inundation	5	6	0.02	0.06
	12.0	17	0.04	0.17
	25.0	36	0.09	0.37
	50.0	108	0.27	1.10
	100.0	129	0.33	1.32
	200.0	194	0.49	1.97
After Inundation	200	220	0.56	2.24
	400	305	0.77	3.10
	800	400	1.02	4.06
				1.25
				Applied Stress (Kpa)
				200
				Collapse Potential
				0.26



Reported by: 
Laboratory Technician

Checked by: 
Laboratory Team Representative



Approved by: 
GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Addis Ababa, Testing Laboratory

CORE/GR/11/A

Measurement of Collapse Index of soils (ASTM 533-96)

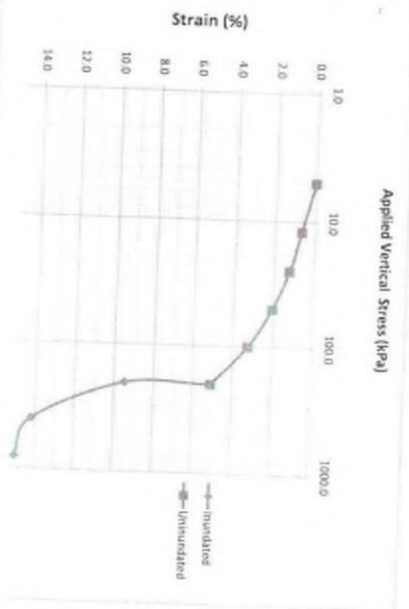
Project : Adama – Km50 Expressway
Client : JMC Projects (India) Ltd.
Sample of : Undisturbed Sample of Collapsible Soil
Station : 8+900 RHS
Depth : 1m
Visual Material Description :

Lab No : 2101-23
Date Tested : 23/5/2023
Date Reported : 5/6/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.39
Field Dry Density (g/cm ³)	1.25
Field Moisture Content (%)	...
Final Water content (%)	31
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.519
Initial Void Ratio (e ₀)	1.015
Ring Factor (mm)	0.00254

Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
5	0.00	0.00	0.00	1.02
12.0	66	0.17	0.67	1.00
25.0	121	0.31	1.23	0.99
50.0	202	0.51	2.05	0.97
100.0	320	0.81	3.25	0.95
200.0	500	1.27	5.08	0.91
200	930	2.36	9.45	0.82
400	1396	3.55	14.18	0.73
800	1475	3.75	14.99	0.71
After Inundation				
Before Inundation				
Collapse Potential				
4.37				



Remark :

Reported by :
Laboratory Technician

Checked by :
Laboratory Team Representative



Approved by :
GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/11/17A

Measurement of Collapse Index of soils (ASTM 5333-96)

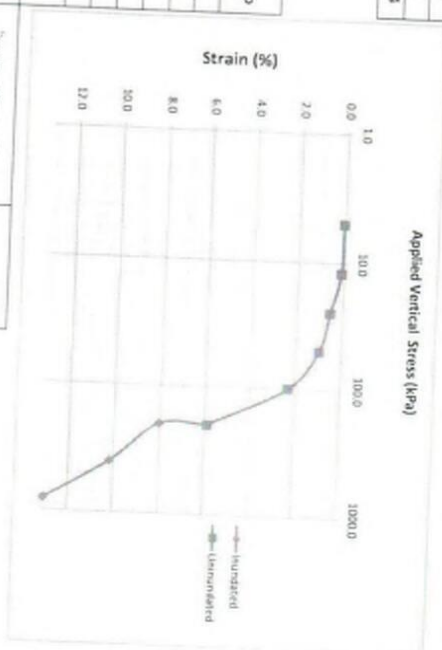
Project : Adama - Km60 Expressway
Client : JMC Projects (India) Ltd
Sample of : Undisturbed Sample of Collapsible Soil
Station : 9+100 LHS
Depth : 1m
Visual Material Description :

Lab No : 2101-23
Date Tested : 1/6/2023
Date Reported : 5/6/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.51
Field Dry Density (g/cm ³)	1.180
Field Moisture Content (%)	---
Final Water content (%)	28.02
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.490
Initial Void Ratio (e ₀)	1.110
Ring Factor (mm)	0.00254

Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Before Inundation		After Inundation	
			Strain (%)	Void Ratio	Applied Stress (kpa)	Collapse Potential
5	5	0.01	0.05	1.11	200	2.15
12.0	11	0.03	0.11	1.11		
25.0	53	0.13	0.54	1.10		
50.0	96	0.24	0.98	1.09		
100.0	227	0.58	2.31	1.06		
200.0	578	1.47	5.87	0.99		
	790	2.01	8.03	0.94		
	1000	2.54	10.16	0.90		
	1285	3.26	13.06	0.83		



Remark :

Reported by :
Laboratory Technician

Checked by :

Laboratory Team Representative



GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/1117A

Measurement of Collapse Index of soils (ASTM 5333-96)

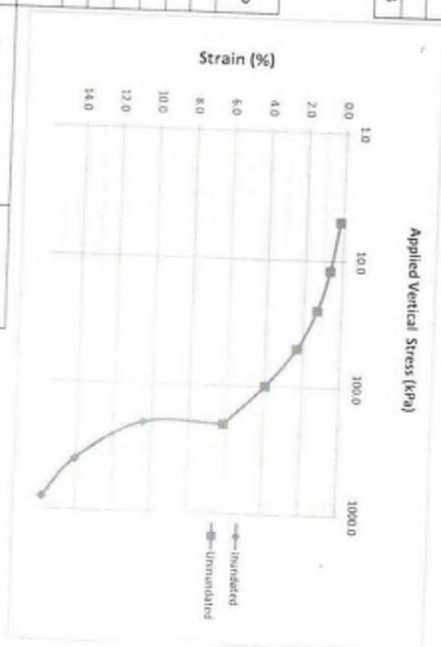
Project: Adama - Km60 Expressway
Client: JMC Projects (India) Ltd.
Sample of: Undisturbed Sample of Collapsible Soil
Station: 9+300 CL
Depth: 1m
Visual Material Description:

Lab No: 2101-23
Date Tested: 1/6/2023
Date Reported: 5/6/2023
Reported to: JMC Projects (India) Ltd.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.24
Field Dry Density (g/cm ³)	1.12
Field Moisture Content (%)	---
Final Water content (%)	32.24
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.417
Initial Void Ratio (e ₀)	1.158
Ring Factor (mm)	0.00254

Before Inundation					After Inundation	
Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Strain (%)	Applied Stress (Kpa)
5	17	0.04	0.17	1.15		
12.0	65	0.17	0.66	1.14		
25.0	128	0.33	1.30	1.13		
50.0	228	0.58	2.32	1.11		
100.0	391	0.99	3.97	1.07		
200.0	600	1.52	6.10	1.03		
200	1029	2.61	10.45	0.93	Collapse Potential	200
400	1384	3.52	14.06	0.85		
800	1555	3.95	15.80	0.82		
					4.0	
					5.0	
					6.0	
					7.0	
					8.0	
					9.0	
					10.0	
					11.0	
					12.0	
					13.0	
					14.0	



Remark:

Reported by: [Signature]
Laboratory Technician

Checked by: [Signature]
Laboratory Team Representative



Approved by: [Signature]
GE Directorate Director
P.02600-08/2020/0001

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GER/1717A

Measurement of Collapse Index of soils (ASTM 533-96)

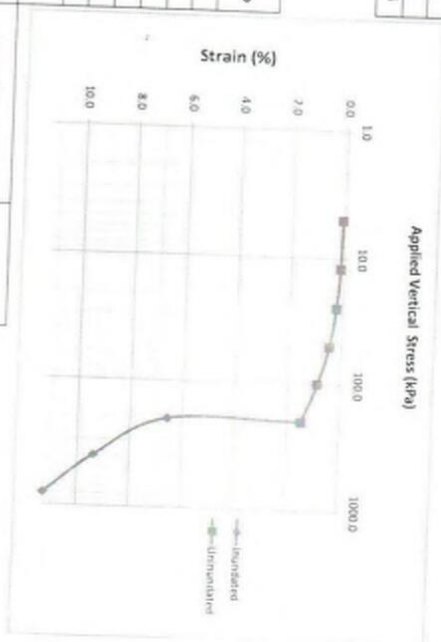
Project: Adama – Jimb0 Expressway
 Client: JMC Projects (India) Ltd.
 Sample of: Undisturbed Sample of Collapsible Soil
 Station: 9+300 CL
 Depth: 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 30/5/2023
 Date Reported: 5/6/2023
 Reported to: JMC Projects (India) Ltd.
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.44
Field Dry Density (g/cm ³)	1.22
Field Moisture Content (%)	---
Final Water content (%)	39.66
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.555
Initial Void Ratio (e ₀)	1.094
Ring Factor (mm)	0.00254

	Before Inundation				After Inundation	
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
	5	8	0.02	0.08	1.09	
	12.0	12	0.03	0.12	1.09	
	25.0	23	0.06	0.23	1.09	
	50.0	45	0.11	0.46	1.08	
	100.0	85	0.22	0.86	1.08	
	200.0	143	0.36	1.45	1.06	
	200	648	1.65	6.58	0.96	
	400	922	2.34	9.37	0.90	Applied Stress (Kpa)
	800	1110	2.82	11.28	0.86	Collapse Potential
						5.13



Remark :

Reported by: 
 Laboratory Technician

Checked by: 
 Laboratory Team Representative



Approved by: 
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Materials Testing Laboratory

CORE/GER/11/1A

Measurement of Collapse Index of soils (ASTM 5333-96)

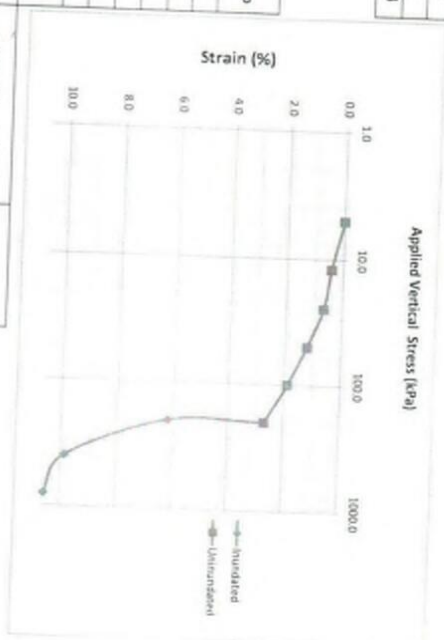
Project: Adama – Kms0 Expressway
 Client: JMC Projects (India) Ltd.
 Sample of: Undisturbed Sample of Collapsible Soil
 Station: 9+500 RHS
 Depth: 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 1/6/2023
 Date Reported: 5/6/2023
 Reported to: JMC Projects (India) Ltd.
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.26
Field Dry Density (g/cm ³)	1.03
Field Moisture Content (%)	---
Final Water content (%)	34.93
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.495
Initial Void Ratio (e ₀)	1.422
Ring Factor (mm)	0.00254

	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio
Before Inundation	5	0.00	0.00	0.00	1.42
	12.0	41	0.10	0.42	1.41
	25.0	65	0.17	0.66	1.41
	50.0	120	0.30	1.22	1.39
	100.0	185	0.47	1.88	1.38
	200.0	265	0.67	2.69	1.36
	200	610	1.55	6.20	1.27
After Inundation	400	970	2.46	9.86	1.18
	800	1040	2.64	10.57	1.17
					Applied Stress (Kpa) 200
					Collapse Index 3.51



Remark:

Reported by:
 Laboratory Technician

Checked by:
 Laboratory Team Representative



Approved by:
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/RT/11/7A

Measurement of Collapse Index of soils (ASTM 5333-96)

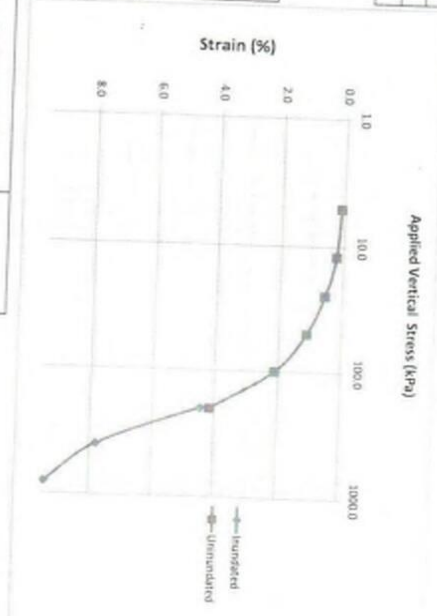
Project : Adama - Km60 Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station: 9+700 RHS
 Depth : 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 10/5/2023
 Date Reported: 5/6/2023
 Reported to : JMC Projects (India) Ltd.
 Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.75
Field Dry Density (g/cm ³)	1.41
Field Moisture Content (%)	---
Final Water content (%)	23.48
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.573
Initial Void Ratio (e ₀)	0.825
Ring Factor (mm)	0.00254

	Before Inundation				After Inundation	
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
	5	9	0.02	0.09	0.82	
	12.0	22	0.06	0.22	0.82	
	25.0	55	0.14	0.56	0.81	
	50.0	109	0.28	1.11	0.80	
	100.0	208	0.53	2.11	0.79	
	200.0	408	1.04	4.15	0.75	
	200	440	1.12	4.47	0.74	
	400	766	1.95	7.78	0.68	
	800	930	2.36	9.45	0.65	
						Applied Stress (Kpa) 200
						Collapse Potential 0.33



Remark :

Reported by : [Signature]
 Laboratory Technician

Checked by : [Signature]
 Laboratory Team Representative



Approved by : [Signature]
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/RI/117A

Measurement of Collapse Index of soils (ASTM 533-96)

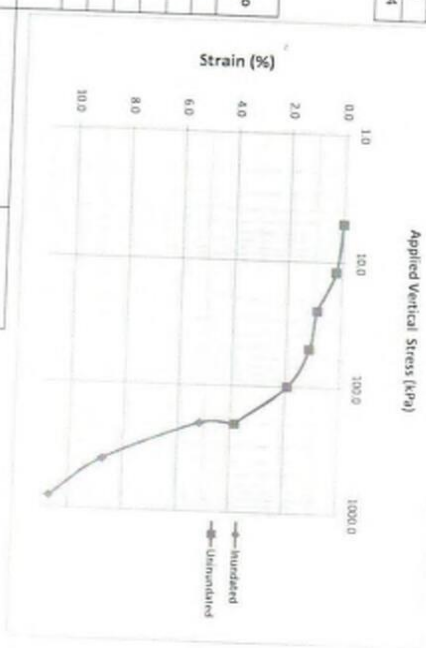
Project: Adama - Km80 Expressway
 Client: JMC Projects (India) Ltd
 Sample of: Undisturbed Sample of Collapsible Soil
 Station: 9+900 CL
 Depth: 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 26/4/2023
 Date Reported: 6/6/2023
 Reported to: JMC Projects (India) Ltd
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.43
Field Dry Density (g/cm ³)	0.97
Field Moisture Content (%)	---
Final Water Content (%)	47
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.522
Initial Void Ratio (e ₀)	1.600
Ring Factor (mm)	0.00254

Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	After Inundation	
					Applied Stress (kpa)	Collapse Potential
5	0.00	0.00	0.00	1.60	200	1.33
12.0	23	0.06	0.23	1.59		
25.0	87	0.22	0.86	1.58		
50.0	111	0.28	1.13	1.57		
100.0	189	0.48	1.92	1.55		
200.0	378	0.96	3.84	1.50		
200	509	1.29	5.17	1.47		
400	861	2.19	8.75	1.37		
800	1052	2.67	10.69	1.32		



Remark:

Reported by: [Signature]
 Laboratory Technician

Checked by: [Signature]
 Laboratory Team Representative



Approved by: [Signature]
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Materials Testing Laboratory

CORE/CEIR/1717A

Measurement of Collapse Index of soils (ASTM 5333-96)

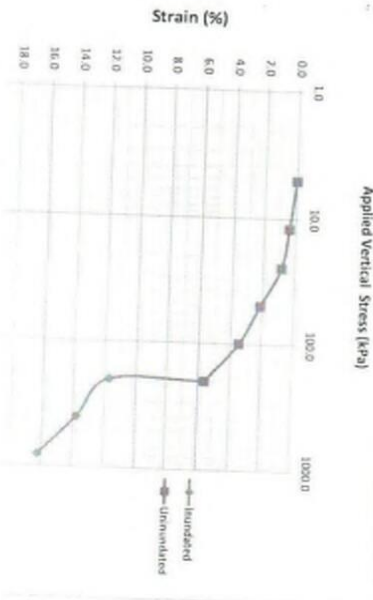
Project: Adama - Km60 Expressway
 Client: JMC Projects (India) Ltd.
 Sample of: Undisturbed Sample of Collapsible Soil
 Station: 10+100 RHS
 Depth: 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 15/5/2023
 Date Reported: 5/6/2023
 Reported to: JMC Projects (India) Ltd.
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.25
Field Dry Density (g/cm ³)	0.98
Field Moisture Content (%)	---
Final Water content (%)	27.95
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.487
Initial Void Ratio (e ₀)	1.538
Ring Factor (mm)	0.00254

	Before Inundation				After Inundation	
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
	5	0.00	0.00	0.00	1.54	
	12.0	40	0.10	0.41	1.53	
	25.0	83	0.21	0.84	1.52	
	50.0	210	0.53	2.13	1.48	
	100.0	340	0.86	3.45	1.45	
	200.0	550	1.40	5.59	1.40	
	200	1154	2.93	11.72	1.24	
	400	1356	3.44	13.78	1.19	
	800	1599	4.06	16.25	1.13	
						Applied Stress (Kpa) 200
						Collapse Potential 6.14



Remark :

Reported by :

[Signature]
 Laboratory Technician

Checked by :

[Signature]
 Laboratory Team Representative



Approved by :

[Signature]
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/R/117A

Measurement of Collapse Index of soils (ASTM 533-96)

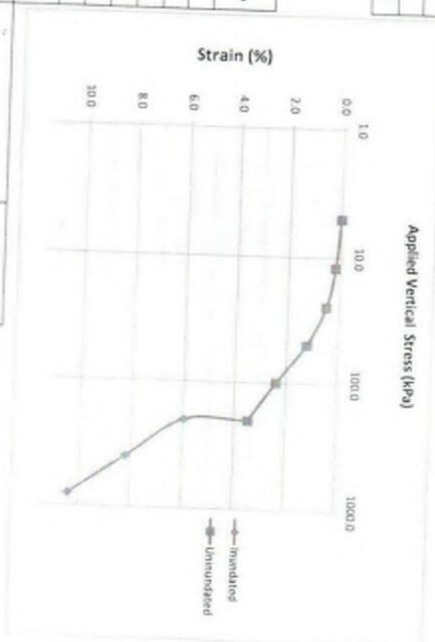
Project: Adama - Kmt60 Expressway
Client: JMC Projects (India) Ltd.
Sample of: Undisturbed Sample of Collapsible Soil
Station: 10+300 LHS
Depth: 2m
Visual Material Description:

Lab No: 2101-23
Date Tested: 4/5/2023
Date Reported: JMC Projects (India) Ltd.
Reported to: Yencomat Construction P.L.C.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.35
Field Dry Density (g/cm ³)	1.01
Field Moisture Content (%)	---
Final Water Content (%)	34.09
Specimen Diameter (mm)	63.5
Initial height h_0 (mm)	25

Sp Gravity	2.536
Initial Void Ratio (e_0)	1.511
Ring Factor (mm)	0.00254

Before Inundation					After Inundation	
Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Strain (%) 40 60 80 100	Applied Stress (kpa) 200
5	0.00	0.00	0.00	1.51		
12.0	18	0.05	0.18	1.51		
25.0	49	0.12	0.50	1.50		
50.0	120	0.30	1.22	1.48		
100.0	235	0.60	2.39	1.45		
200.0	340	0.86	3.45	1.42		
200	587	1.49	5.96	1.36	Collapse Potential 2.51	
400	808	2.05	8.21	1.30		
800	1025	2.60	10.41	1.25		



Remark :

Reported by: 
Laboratory Technician

Checked by: 
Laboratory Team Representative



Approved by: 
Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Materials Testing Laboratory

CORE/GJRF/1117A

Measurement of Collapse Index of soils (ASTM 5333-96)

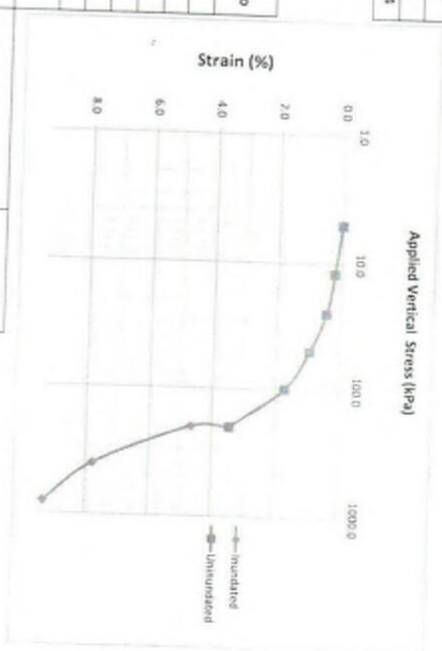
Project : Adama - Km80 Expressway
Client : JMC Projects (India) Ltd.
Sample of : Undisturbed Sample of Collapsible Soil
Station : 10+500 CL
Depth : 2m
Visual Material Description :

Lab No : 2101-23
Date Tested : 10/5/2023
Date Reported : 5/6/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.69
Field Dry Density (g/cm ³)	1.39
Field Moisture Content (%)	---
Final Water content (%)	23.41
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.517
Initial Void Ratio (e ₀)	0.811
Ring Factor (mm)	0.00254

	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio		
						Applied Stress (kpa)	
Before Inundation	5	0.00	0.00	0.00	0.81		
	12.0	21	0.05	0.21	0.81		
	25.0	44	0.11	0.45	0.80		
	50.0	94	0.24	0.96	0.79		
	100.0	170	0.43	1.73	0.78		
	200.0	339	0.86	3.44	0.75		
After Inundation	200	460	1.17	4.67	0.73		
	400	765	1.94	7.77	0.67		
	800	920	2.34	9.35	0.64		
						Applied Stress (kpa)	200
						Collapse Potential	1.23



Remark :

Reported by :
Laboratory Technician

Checked by :
Laboratory Team Representative



Approved by :
GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/1117A

Measurement of Collapse Index of soils (ASTM 5333-96)

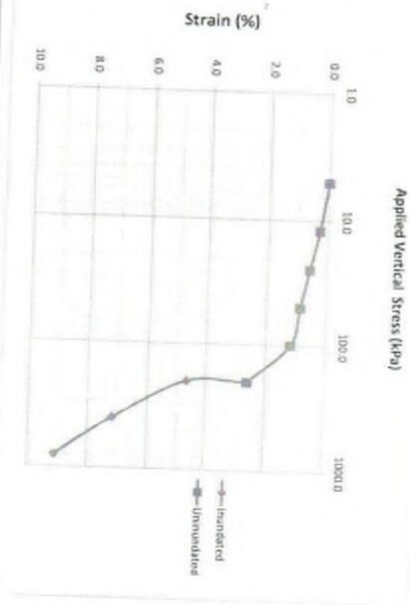
Project: Adama - Km60 Expressway
Client: JMC Projects (India) Ltd
Sample of: Undisturbed Sample of Collapsible Soil
Station: 10+700 CL
Depth: 2m
Visual Material Description:

Lab No: 2101-23
Date Tested: 25/5/2023
Date Reported: 5/6/2023
Reported to: JMC Projects (India) Ltd.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.72
Field Dry Density (g/cm ³)	1.34
Field Moisture Content (%)	---
Final Water content (%)	28.9
Specimen Diameter (mm)	63.5
Initial Height h ₀ (mm)	25

Sp Gravity	2.508
Initial Void Ratio (e ₀)	0.872
Ring Factor (mm)	0.00254

Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Applied Stress (Kpa)
5	0.00	0.00	0.00	0.87	200
12.0	27	0.07	0.27	0.87	
25.0	57	0.14	0.58	0.86	
50.0	85	0.22	0.86	0.86	
100.0	114	0.29	1.16	0.85	
200.0	256	0.65	2.60	0.82	
200	460	1.17	4.67	0.78	
400	705	1.79	7.16	0.74	200
800	894	2.27	9.08	0.70	
After Inundation					Collapse Potential
					2.07



Remark :

Reported by: 
Laboratory Technician

Checked by: 
Laboratory Team Representative



Approved by: 
GE Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GUR/11/A

Measurement of Collapse Index of soils (ASTM 5333-96)

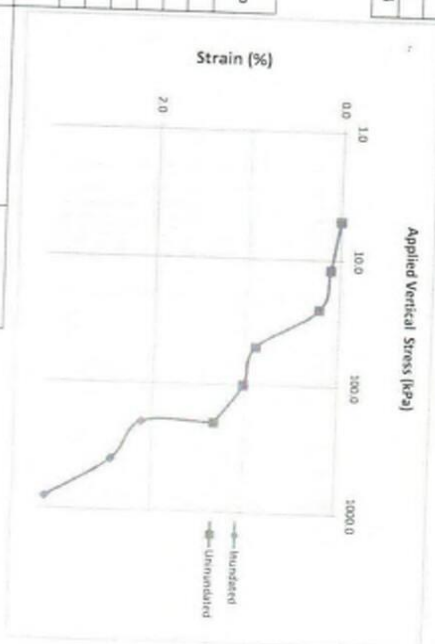
Project: Adama - Km60 Expressway
Client: JMC Projects (India) Ltd.
Sample of: Undisturbed Sample of Collapsible Soil
Station: 10+900 LHS
Depth: 2m
Visual Material Description:

Lab No: 2101-23
Date Tested: 15/5/2023
Date Reported: 5/6/2023
Reported to: JMC Projects (India) Ltd.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.65
Field Dry Density (g/cm ³)	1.19
Field Moisture Content (%)	23.06
Final Water content (%)	23.06
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.478
Initial Void Ratio (e ₀)	1.082
Ring Factor (mm)	0.00254

	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
Before Inundation	5	0.00	0.00	0.00	1.08	
	12.0	10	0.03	0.10	1.08	
	25.0	21	0.05	0.21	1.08	
	50.0	88	0.22	0.89	1.06	
	100.0	100	0.25	1.02	1.06	
	200.0	130	0.33	1.32	1.05	
After Inundation	200	208	0.53	2.11	1.04	
	400	240	0.61	2.44	1.03	Applied Stress (kpa)
	800	310	0.79	3.15	1.02	Collapse Potential



Remark:

Reported by:
Laboratory Technician

Checked by:
Laboratory Team Representative



Approved by:
GE Directorate Director

Publication: 2023/05/05

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GER/11/17A

Measurement of Collapse Index of soils (ASTM 5333-96)

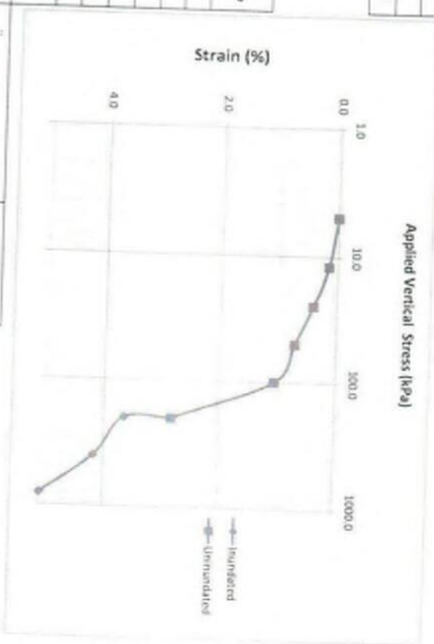
Project : Adama - Kirebo Expressway
Client : JMC Projects (India) Ltd
Sample of : Undisturbed Sample of Collapsible Soil
Station : 11+100 LHS
Depth : 2m
Visual Material Description: _____

Lab No: 2101-23
Date Tested: 18/5/2023
Date Reported: 5/6/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.79
Field Dry Density (g/cm ³)	1.49
Field Moisture Content (%)	---
Final Water content (%)	19.79
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp. Gravity	2.549
Initial Void Ratio (e ₀)	0.711
Ring Factor (mm)	0.00254

Before Inundation					After Inundation	
Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Strain (%)	
5	0.00	0.00	0.00	0.71	2.0	
12.0	15	0.04	0.15	0.71	4.0	
25.0	40	0.10	0.41	0.70		
50.0	70	0.18	0.71	0.70		
100.0	104	0.26	1.06	0.69		
200.0	280	0.71	2.84	0.66		
200	360	0.91	3.66	0.65		
400	410	1.04	4.17	0.64	Applied Stress (Kpa)	
800	500	1.27	5.08	0.62	Collapse Potential	
					0.81	



Remark :

Reported by :
Laboratory Technician

Checked by :
Laboratory Team Representative



Approved by :
GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GER/1117A

Measurement of Collapse Index of soils (ASTM 5333-96)

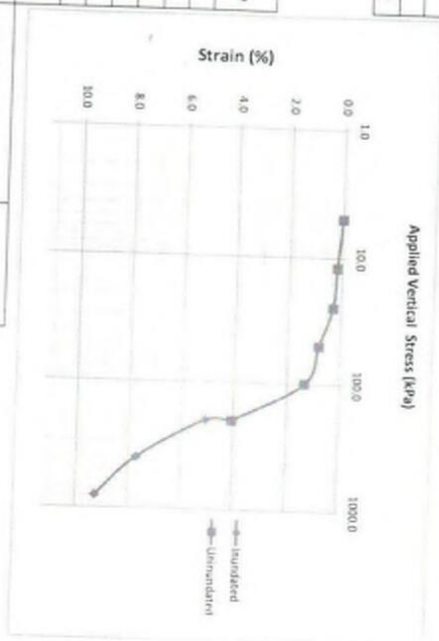
Project : Adama - Km60 Expressway
Client : JMC Projects (India) Ltd.
Sample of : Undisturbed Sample of Collapsible Soil
Station : 11+300 RHS
Depth : 2m
Visual Material Description :

Lab No: 2101-23
Date Tested: 18/5/2023
Date Reported: 5/6/2023
Reported to : JMC Projects (India) Ltd.
Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.38
Field Dry Density (g/cm ³)	1.17
Field Moisture Content (%)	---
Final Water content (%)	39.23
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.432
Initial Void Ratio (e ₀)	1.079
Ring Factor (mm)	0.00254

	Before Inundation				After Inundation	
	Applied Vertical Stress (Kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
	5	0.00	0.00	0.00	1.08	
	12.0	18	0.05	0.18	1.07	
	25.0	30	0.08	0.30	1.07	
	50.0	80	0.20	0.81	1.06	
	100.0	130	0.33	1.32	1.05	
	200.0	388	1.01	4.04	0.99	
	200	500	1.27	5.08	0.97	
	400	758	1.93	7.70	0.92	Applied Stress (Kpa)
	800	910	2.31	9.25	0.89	Collapse Potential
						1.04



Remark :

Reported by :
Laboratory Technician

Checked by :

Laboratory Team Representative



Approved by :

GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/RT/117A

Measurement of Collapse Index of soils (ASTM 5333-96)

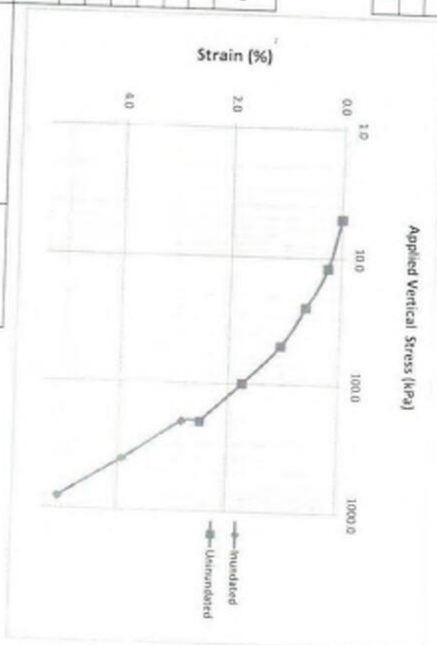
Project : Adama - Km60 Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station : 11+500 CL
 Depth : 2m
 Visual Material Description: _____

Lab No: 2101-23
 Date Tested: 10/5/2023
 Date Reported: 5/6/2023
 Reported to : JMC Projects (India) Ltd.
 Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.89
Field Dry Density (g/cm ³)	1.47
Field Moisture Content (%)	---
Final Water content (%)	37.52
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.546
Initial Void Ratio (e ₀)	0.732
Ring Factor (mm)	0.00254

	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	Applied Stress (kpa)	
Before Inundation	5	0.00	0.00	0.00	0.73	200	Collapse Potential
	12.0	23	0.06	0.23	0.73		
	25.0	61	0.15	0.62	0.72		
	50.0	104	0.26	1.06	0.71		
	100.0	172	0.44	1.75	0.70		
	200.0	247	0.63	2.51	0.69		
After Inundation	200	290	0.71	2.84	0.68	200	Collapse Potential
	400	387	0.98	3.93	0.66		
	800	500	1.27	5.08	0.64		



Remark :

Reported by : [Signature]
 Laboratory Technician

Checked by : [Signature]
 Laboratory Team Representative



Approved by : [Signature]
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/MT/117A

Measurement of Collapse Index of soils (ASTM 5333-96)

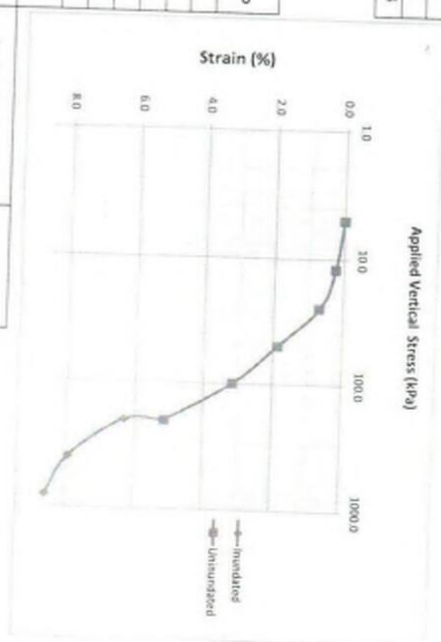
Project: Adama - Kire60 Expressway
 Client: JMC Projects (India) Ltd
 Sample of: Undisturbed Sample of Collapsible Soil
 Station: 11+700 RHS
 Depth: 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 26/4/2023
 Date Reported: 5/6/2023
 Reported to: JMC Projects (India) Ltd.
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.34
Field Dry Density (g/cm ³)	1.13
Field Moisture Content (%)	---
Final Water content (%)	33.37
Specimen Diameter (mm)	63.5
Initial height h _z (mm)	25

Sp. Gravity	2.492
Initial Void Ratio (e ₀)	1.205
Ring Factor (mm)	0.00254

	Before Inundation		After Inundation	
	Applied Vertical Stress (kpa)	Dial reading Corrected Dial reading (mm)	Strain (%)	Void Ratio
	5	0.00	0.00	1.21
	12.0	23	0.06	1.20
	25.0	67	0.17	1.19
	50.0	185	0.47	1.16
	100.0	310	0.79	1.14
	200.0	505	1.28	1.09
	200	620	1.57	1.07
	400	780	1.98	1.03
	800	845	2.15	1.02
			8.59	
			Applied Stress (Kpa)	200
			Collapse Potential	1.17



Remark :

Reported by :

[Signature]

Laboratory Technician

Checked by :

[Signature]

Laboratory Team Representative

Lab-7214-0114-03-4033

Lab-7214-0114-03-4033



Approved by :

[Signature]

GE Directorate Director

P.O.Box-28601/117A

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GEUR/11/7A

Measurement of Collapse Index of soils (ASTM 5333-96)

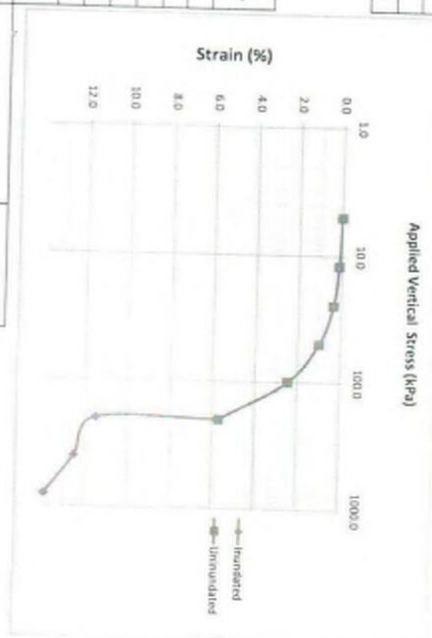
Project : Adama – Km60 Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station: 11+900 LHS
 Depth : 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 15/5/2023
 Date Reported: 5/6/2023
 Reported to : JMC Projects (India) Ltd.
 Reported by : CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.49
Field Dry Density (g/cm ³)	1.18
Field Moisture Content (%)	---
Final Water content (%)	24.95
Specimen Diameter (mm)	63.5
Initial height h _o (mm)	25

So Gravity	2.487
Initial Void Ratio (e _o)	1.108
Ring Factor (mm)	0.00254

	Before Inundation				After Inundation	
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
Before Inundation	5	0.00	0.00	0.00	1.11	
	12.0	12	0.03	0.12	1.11	
	25.0	34	0.09	0.35	1.10	
	50.0	98	0.25	1.00	1.09	
	100.0	240	0.61	2.44	1.06	
	200.0	560	1.42	5.69	0.99	
After Inundation	200	1130	2.87	11.48	0.87	
	400	1229	3.12	12.49	0.84	Applied Stress (Kpa)
	800	1365	3.47	13.87	0.82	Collapse Potential



Reported by :
 Laboratory Technician

Checked by :
 Laboratory Team Representative

Approved by :
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Materials Testing Laboratory

CORE/CL/RT/17A

Measurement of Collapse Index of soils (ASTM 5333-96)

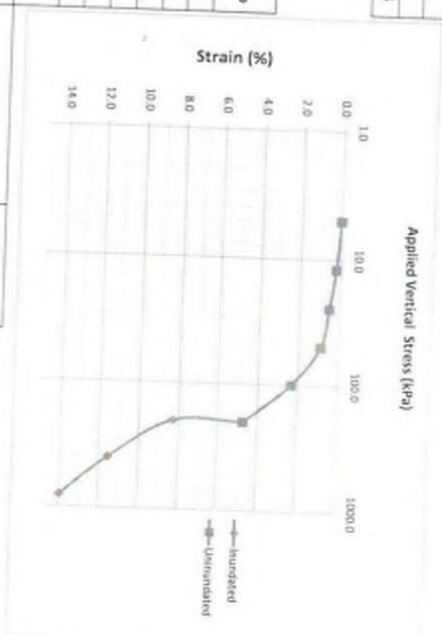
Project : Adama - Kribi Expressway
 Client : JMC Projects (India) Ltd.
 Sample of : Undisturbed Sample of Collapsible Soil
 Station : 12+100 CL
 Depth : 2m
 Visual Material Description:

Lab No: 2101-23
 Date Tested: 26/4/2023
 Date Reported: 5/6/2023
 Reported to: JMC Projects (India) Ltd.
 Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.46
Field Dry Density (g/cm ³)	1.25
Field Moisture Content (%)	---
Final Water content (%)	28.92
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.426
Initial Void Ratio (e ₀)	0.941
Ring Factor (mm)	0.00254

Before inundation					After inundation	
Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio		
5	0.00	0.00	0.00	0.94		
12.0	21	0.05	0.21	0.94		
25.0	50	0.13	0.51	0.93		
50.0	87	0.22	0.88	0.92		
100.0	229	0.58	2.33	0.90		
200.0	464	1.18	4.71	0.85		
200	815	2.07	8.28	0.78		
400	1135	2.88	11.53	0.72		
800	1374	3.49	13.96	0.67		
					Applied Stress (Kpa)	200
					Collapse Potential	3.57



Remark :

Reported by : [Signature]
 Laboratory Technician

Checked by : [Signature]
 Laboratory Team Representative



Approved by : [Signature]
 GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C. Materials Testing Laboratory

CORE/GEIR/111/A

Measurement of Collapse Index of soils (ASTM 5333-96)

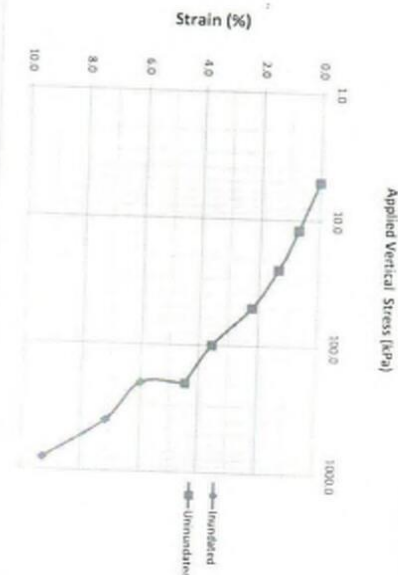
Project: Adama - Km60 Expressway
Client: JMC Projects (India) Ltd.
Sample of: Undisturbed Sample of Collapsible Soil
Station: 12+300 RHS
Depth: 2m
Visual Material Description:

Lab No: 2101-23
Date Tested: 3/4/2023
Date Reported: 5/6/2023
Reported to: JMC Projects (India) Ltd.
Reported by: CORE Consulting Engineers P.L.C.

Field Bulk Density (g/cm ³)	1.59
Field Dry Density (g/cm ³)	1.20
Field Moisture Content (%)	---
Final Water content (%)	32.89
Specimen Diameter (mm)	63.5
Initial height h ₀ (mm)	25

Sp Gravity	2.480
Initial Void Ratio (e ₀)	1.075
Ring Factor (mm)	0.00254

	Before Inundation				After Inundation	
	Applied Vertical Stress (kpa)	Dial reading	Corrected Dial reading (mm)	Strain (%)	Void Ratio	
	5	0.00	0.00	0.00	1.08	
	12.0	68	0.17	0.69	1.06	
	25.0	132	0.34	1.34	1.05	
	50.0	218	0.55	2.21	1.03	
	100.0	350	0.89	3.56	1.00	
	200.0	438	1.11	4.45	0.98	
	200	590	1.50	5.99	0.95	
	400	704	1.79	7.15	0.93	
	800	911	2.31	9.26	0.88	
						Applied Stress (kpa) 200
						Collapse Potential 1.54



Remark :

Reported by: 
Laboratory Technician

Checked by: 
Laboratory Team Representative



Approved by: 
GE Directorate Director

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project

CORE Consulting Engineers P.L.C Materials Testing Laboratory

CORE/GE/IR/11/1A

Measurement of Collapse Index of soils (ASTM 5333-96)

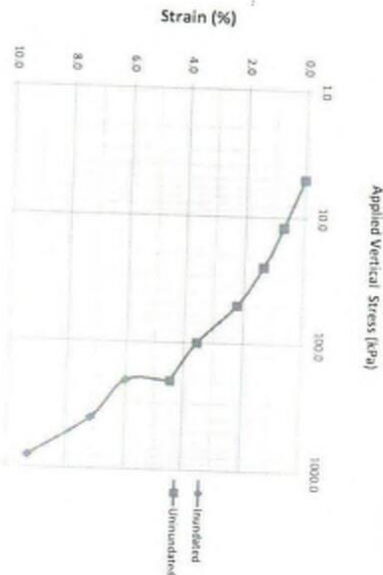
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	400	704	1.79	7.15	0.93	Applied Stress (Kpa)
	800	911	2.31	9.26	0.88	Collapse Potential
						1.54



Remark :

Reported by:

[Signature]
Laboratory Technician

Checked by:

[Signature]
Laboratory Team Representative



Approved by:

[Signature]
GE Directorate Director

Annex-1

GPS XY Coordinates for each sample test pits

Coordinates				
Serial No	Chainage	Easting	Northing	Remark
1	7+300	538393.909	949425.481	
2	7+500	538408.662	949624.936	
3	7+700	538423.414	949824.391	
4	7+900	538443.814	950023.278	
5	8+100	538490.762	950217.487	
6	8+300	538566.917	950402.207	
7	8+500	538670.478	950573.076	
8	8+700	538798.767	950726.278	
9	8+900	538939.118	950868.759	
10	9+100	539079.836	951010.880	
11	9+300	539220.554	951153.002	
12	9+500	539361.272	951295.123	
13	9+700	539501.990	951437.244	
14	9+900	539642.708	951579.365	
15	10+100	539783.426	951721.487	
16	10+300	539924.131	951863.621	
17	10+500	540063.942	952006.633	
18	10+700	540202.317	952151.035	
19	10+900	540339.240	952296.815	
20	11+100	540474.699	952443.956	
21	11+300	540608.680	952592.444	
22	11+500	540741.169	952742.265	
23	11+700	540872.155	952893.405	
24	11+900	541002.272	953045.296	
25	12+100	541129.669	953199.478	
26	12+300	541257.425	953353.355	

Annex-2

All Test Result for Treated and Untreated Soil

ALL TEST RESULT FOR TREATED AND UNTREATED SOIL							
Tests	0%	10%	20%	30%	40%	50%	Marble
Maximum Dry Density (MDD)	1.44	1.505	1.732	1.775	1.843	1.836	2.255
OMC	18.2	16.2	15.1	14.6	12.2	10.4	5.8
Liquid Limit (LL)	43.25	39.4	36.45	34.1	31.94	27.42	NP
PL	28.69	26.16	24.62	22.41	21.198	19.2	
Platic Index (PI)	14.56	13.24	11.83	11.69	10.74	8.22	
California Bearing Ratio (CBR)	22	25	27	39	35.5	31.5	-
Swelling Index (SI)	0.71	0.54	0.44	0.41	0.42	0.43	-
Specific Gravity (SG)	2.558	-	-	-	-	-	2.728
Collapse Index (CI)	9.08	7.42	5.13	3.11	2.7	1.2	-
Cohesion, C (Un soaked)	22	20.2	18.3	16.9	15.3	14.2	-
Cohesion, C (Soaked)	20.6	18.84	17.4	15.74	14.74	13.6	-
Angle of internal friction (Un soaked)	13.82	15.1	16.91	18	19.49	20.6	-
Angle of internal friction (Soaked)	14.68	16.33	17.43	18.91	19.9	21.2	-

Annex-3

Photo for test pit at each station



Chainage at 7+500 RHS

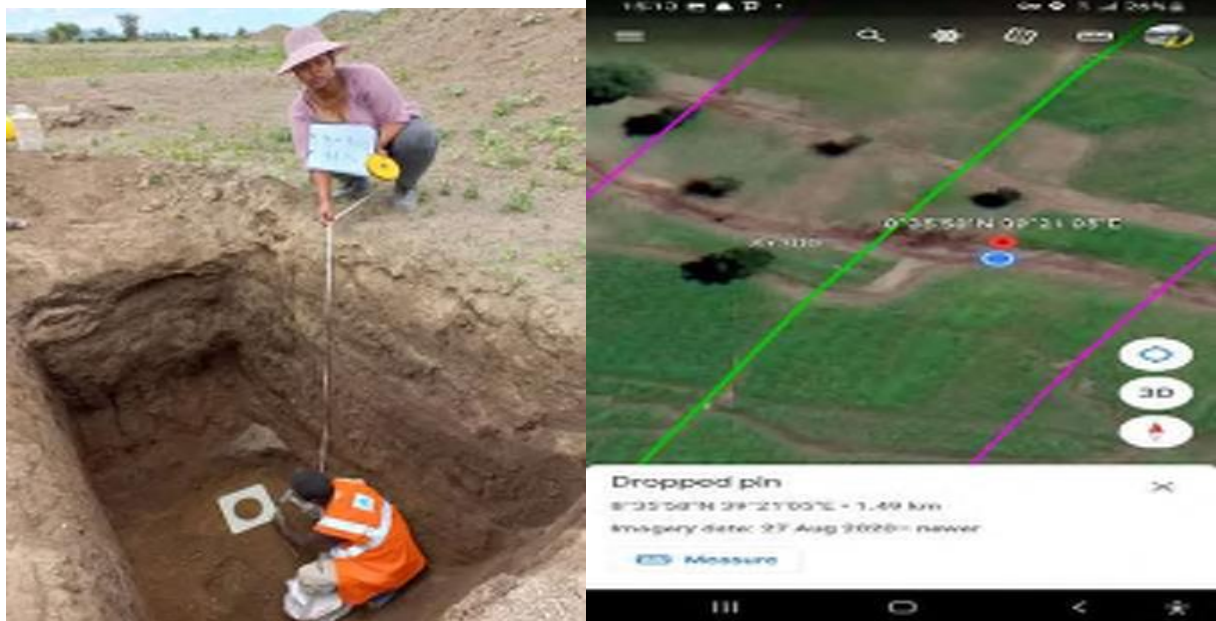


Chainage at 7+700 Center



Chainage at 8+100 Centre

The Study of Collapsible Soil Mixed with Waste Marble Dust: in Case Adama-Awash Road Project



Chainage at 8+300 RHS



Chainage at 8+500 LHS



Chainage at 8+700 Centre





Chainage at 9+300 Centre



Chainage at 9+500 RHS



Chainage at 9+700 LHS



Chainage at 9+900 Centre



Chainage at 10+100 RHS



Chainage at 10+300 LHS



Chainage at 10+500 Centre



Chainage at 10+700 RHS



Chainage at 10+900 LHS



Chainage at 11+100 Centre



Chainage at 11+300 RHS



Chainage at 11+500 Centre



Chainage at 11+700 RHS



Chainage at 11+900 LHS



Sample Packing and sending to Laboratory for testing



Empty Mould