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Enhancing Cement Stabilization for Lateritic Soil in the Takie Area of Ogbomoso

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ABSTRACT

The study investigates "Optimizing Cement Stabilization for Lateritic Soil in the Takie Area of Ogbomoso" and presents a comprehensive analysis of geotechnical properties. The research encompassed particle size determination and Atterberg limits testing to classify the samples, primarily composed of lateritic soil. The results detailed the particle size distribution and indicated the soil's composition, predominantly sand with gravel and unaccounted finer silt content. The Atterberg limits testing revealed variations in plastic and liquid limits across different cement percentages. Additionally, dynamic and static compaction tests were performed, indicating Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The static compaction involved replacing proportions of bulk sand with cement for each percentage addition. The study achieved its objective of understanding soil properties for stabilization purposes, offering insights into the impact of varying cement content on soil characteristics and compaction. The abstract emphasizes the comprehensive investigation into lateritic soil properties and the influence of cement stabilization, vital for engineering applications in the Takie area of Ogbomoso.

Keywords: Lateritic Soil, Cement Stabilization, Geotechnical Properties, Atterberg Limits, Compaction Testing

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1. INTRODUCTION

The successful stabilization of lateritic soil stands as a pivotal challenge in numerous construction and engineering projects, particularly in regions like the Takie area of Ogbomoso. This soil type, abundant in the area, presents unique challenges due to its innate characteristics, including low load-bearing capacity and susceptibility to erosion. Cement stabilization offers a promising solution, yet the optimization of cement content for effective stabilization remains a critical area of exploration (Firoozi *et al.*, 2017). Understanding the specific requirements for achieving stability in this particular soil type is paramount for sustainable construction and infrastructure development.

This study aims to delve into the precise determination of the optimum cement content necessary to enhance the engineering properties of lateritic soil in the Takie area, ensuring improved load-bearing capacity and overall stability for various construction applications. Through a comprehensive analysis of cement-soil interactions and compaction characteristics, this research endeavors to provide practical insights and recommendations for optimizing cement stabilization in this region, addressing the unique challenges posed by the lateritic soil in Ogbomoso's Takie area.

The Takie area in Ogbomosho, nestled within the Ogbomosho North Local Government area of Oyo State, stands as a key urban hub known for its diverse demographic mix encompassing traders, artisans, private sector workers, civil servants, and students. This vibrant population fuels a robust array of commercial establishments, educational facilities, medical centers, and residential edifices. The area boasts an extensive transportation network catering to a variety of transit modes, from motor vehicles and motorcycles to heavy-duty trucks and pedestrian traffic, all crucial for daily activities. Given this bustling activity, the imperative for a robust soil foundation with superior bearing capacity becomes essential, paralleled by the critical need for well-maintained road structures to support the area's extensive mobility requirements (Adagunodo *et al* 2014).

The escalating cost and limited availability of conventional building construction materials have spurred a search for alternative materials (Vagtholm *et al.,* 2023). Concurrently, challenges in waste disposal have driven geotechnical engineering research towards exploring by-products and waste materials (Liu and Hung, 2023). Industrial activities generate vast quantities of waste, leading to natural resource depletion. Utilizing these waste materials as alternatives presents multiple advantages, including cost-effective stabilization, accessibility to cheaper stabilizers, conservation of natural resources, and the reduction in waste accumulation (Younis *et al.,* 2023). Lateritic soils, rich in iron oxides and aluminum hydroxides, serve as favorable construction materials and are extensively employed in tropical construction, particularly as road materials for sub-grades, sub-bases, and low to medium traffic bases (Emmanuel *et al.,* 2021). Cement stabilization, entailing the addition of small cement quantities to alter soil properties, varies based on the soil's dry weight, type, and desired characteristics. While various cement types can be used for soil stabilization, ordinary Portland cement remains the most commonly employed option (Solihu, 2020).

2. METHODOLOGY

Soil samples sourced from the Takie area in Ogbomoso were subjected to a detailed geotechnical analysis. Special care was taken in their collection and transportation to the geotechnical laboratory to preserve their natural state. The investigation focused on stabilizing the soil through trials involving different cement percentages, ranging from 0% to 6%, in order to pinpoint the optimal cement content for stabilization. The laboratory procedures involved a range of tests to assess the soil's engineering properties. Classification tests such as Sieve Analysis and Atterberg's Limits Tests were conducted to understand the soil's characteristics. The Sieve Analysis utilized various equipment like mechanical sieve vibrators, different-sized sieves, and precise weighing balances to determine the particle size distribution. The process involved segregating the soil sample across sieves, calculating the retained material on each sieve, and deriving the percentage retention.

Further tests included Dry Sieving, applicable to coarser materials but less accurate for finer substances due to energy requirements and surface effects. It involved weighing dried sandy soil, distributing it over sieves, and computing the distribution ratio on each sieve. The determination of the Liquid Limit and Plastic Limit involved meticulous procedures and specific apparatus. For the Liquid Limit, a paste was formed by mixing air-dried soil with distilled water and placed in the Casagrande apparatus, determining the moisture content after a specific number of blows. Similarly, for the Plastic Limit, a paste was created and rolled until it began to crumble, with a portion tested for moisture content to ascertain the average moisture content for the plastic limit.

Another significant aspect was establishing the relationship between dry density and moisture content for soil compaction. Using various tools like compaction moulds and rammers, the investigation aimed to determine the optimum moisture content and maximum dry density by compacting soil at different moisture levels, conducting sieve analysis, and incorporating various percentages of cement. Calculations based on weight differences and moisture content allowed for the plotting of dry densities against respective moisture content, ultimately leading to the determination of the OMC and MDD for the soil under study.

3. RESULTS AND DISCUSSION

3.1 Particle Size Determination Results

Sieve analysis of soil sample using sieve sizes of 20mm, 8mm, 4mm, 2mm, 1mm, 500µm, 250µm, 125µm, 75µm were used to determine the particle size distribution of the samples in which the particle passing were 100%, 94.52%, 77.62%, 65.58%, 55.70%, 27.48%, 21.40%, 12.68%, 10.06% respectively which further shows that soil Sample has a lower clay content of intermediate moderately graded soil sample, The soil sample contains about 34.42% gravel and 65.58% sand which shows a predominantly sand with some percentage soils unaccounted for of finer silt content passing through the 75µmicrons. The result is further presented on Figure 1.

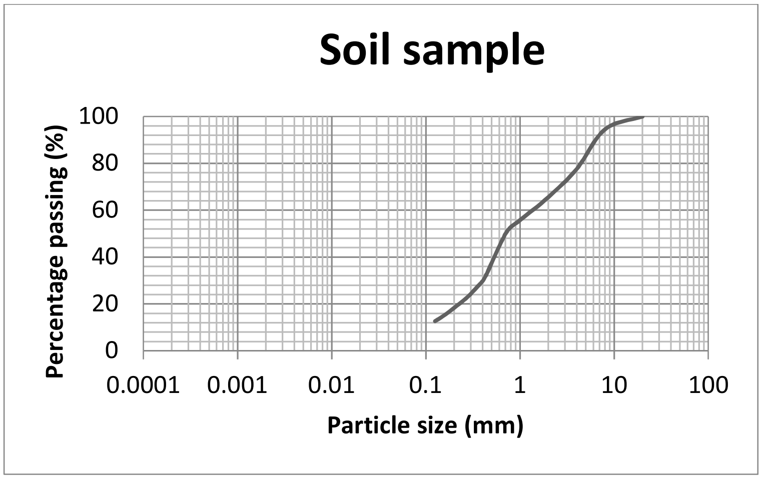

Fig 1: Graph of sieve analysis of the soil sample

3.2 Plastic Limit Determination Results (Atterberg limit)

0% Cement: The determination of the Plastic Limit (Atterberg Limit) involved conducting four trials after moistening a 120g soil sample for 24 hours. These trials yielded results of 41, 35, 27, and 16 blows, corresponding to moisture contents of 18.8%, 18.5%, 23.3%, and 25.4% respectively. The Plastic Limit was determined by rolling the sample until it fractured, resulting in masses of 1.9g and 1.5g with associated moisture contents of 11.8% and 7.1%. The average plastic limit derived from these values was 9.5%. The Plasticity Index, indicating the range of plasticity, was computed by subtracting the Plastic Limit from the Liquid Limit, which was determined at the 25th blow and presented in Fig 2.

2% Cement: A 2% cement mix, applied to a 120g soil sample and allowed to soak for 24 hours, underwent four trials measuring the Atterberg limits to assess the soil's liquidity. These trials yielded results of 16, 20, 27, and 32 blows, correlating with moisture contents of 18.5%, 14.29%, 10.4%, and 7.95% respectively. The plastic limits were established by rolling the sample until fracture, resulting in mass values of 1.9g and 1.5g, alongside moisture contents of 1.2% and 1.0% respectively. The average plastic limit derived from these values equated to 10.1%. The plasticity index, determined by the difference between the plastic and liquid limits, was calculated at 1.9. The most precise or median liquid limit was determined by the liquid limit at the 25th blow, indicated in Figure 3, showcasing the moisture content of the soil at that specific blow count.

4% Cement: A soil sample consisting of 120 grams with a 4% cement composition underwent a 24-hour moisturizing process to ascertain its Atterberg limits. Four trials were conducted to determine the soil's liquidity transition, with corresponding results as follows: 35 blows at 19.64% moisture content, 28 blows at 20.0%, 19 blows at 20.9%, and 13 blows at 23.4%. The plastic limits were identified by rolling the sample until fracture, yielding mass values of 1.9g and 2.0g, with respective moisture contents of 18.75% and 17.65%. The average plastic limit was calculated at 18.20%. The plasticity index, derived by subtracting the plastic limit from the liquid limit, was determined as 2.60%. The most accurate or average liquid limit was established at the 25th blow, depicting the value of the liquid limit corresponding to the moisture content, as illustrated in Figure 4.

6% Cement: A 6% cement addition to a 120g soil sample underwent 24-hour moisturization before four trials were conducted to determine the soil's liquidity through wet-to-dry Atterberg limits testing. These trials yielded results of 17, 22, 31, and 37 blows, corresponding to moisture contents of 19.13%, 20.0%, 23.1%, and 25.6%, respectively. The plastic limits were ascertained by rolling the sample until it fractured, resulting in masses of 1.8g and 1.7g with corresponding moisture contents of 12.5% and 13.3%. The average plastic limit computed from these values is 12.9%. The plasticity index, derived by subtracting the plastic limit from the liquid limit, resulted in a value of 8.6%. The most accurate or average liquid limit was determined at the 25th blow, corresponding to the moisture content, as shown in Fig 5.

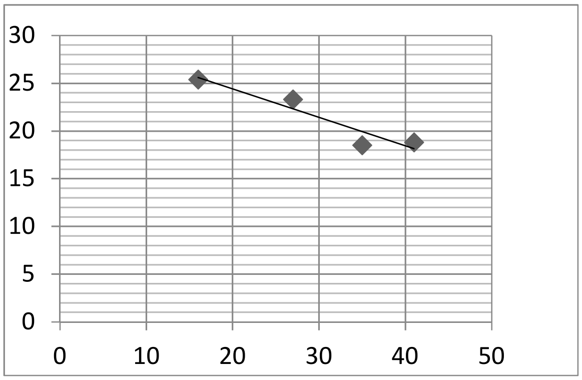

Fig 2: Graph of Atterberg Limits (0% cement)

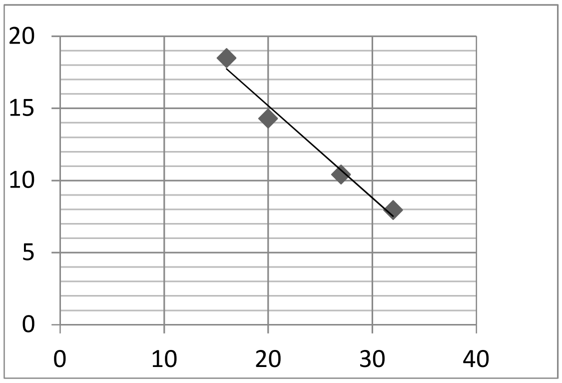

Fig 3: Graph of Atterberg Limits (2% cement)

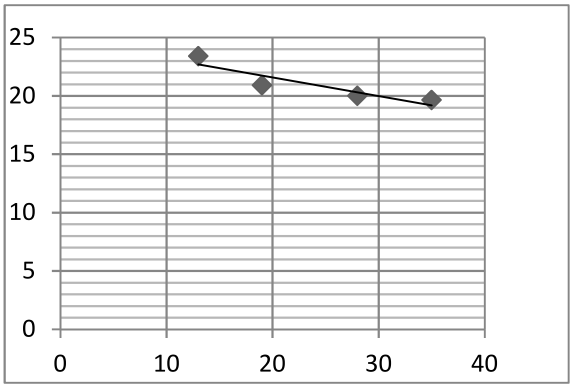

Fig 4: Graph of Atterberg Limits (4% cement)

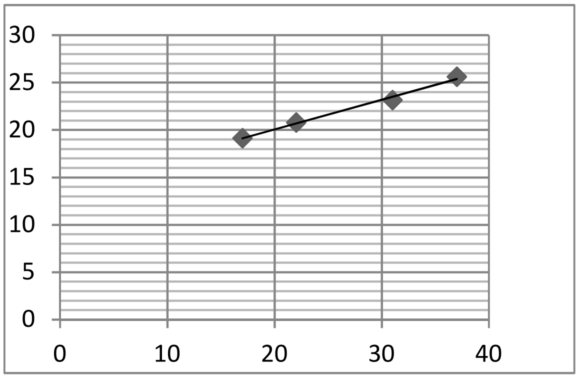

Fig 5: Graph of Atterberg Limits (6% cement

Particle size analysis and Atterberg limits testing were primarily conducted to classify the samples, predominantly consisting of lateritic soil, in this research. This aimed to determine the soil's geotechnical properties, including its liquid limit, plastic limit, and plasticity index. The results, as presented earlier, distinctly demonstrate the presence of clayey and silt content in each sample. Additionally, they reveal the composition of fine, medium, and coarse sand, as well as fine and medium gravel in the samples. Consequently, this comprehensive understanding of the soil's geotechnical characteristics signifies the accomplishment of our initial objective.

3.3 Dynamic Compaction Results

<u>0% Cement</u>: The incremental addition of water leads to a rise in dry density proportionate to the increase in moisture content until a point where further water addition causes a decrease. In this sample, the highest moisture content, specifically the Optimum Moisture Content (OMC), is observed at approximately 9.8% water content. At this moisture level, a corresponding dry density of 1.72g/cm^3 is achieved, as depicted in Figure 6 below.

<u>2% Cement:</u> The incorporation of water into this percentage of cement and soil initially results in a stable effect. This stability is followed by a rise in dry density corresponding to an increase in moisture content until it decreases due to a further increase in water percentage. The highest moisture content, corresponding to the maximum moisture content (OMC) in this sample, is approximately 10.0% of water, resulting in a corresponding dry density of 2.0g/cm³, as depicted in Figure 7. <u>4% Cement:</u> The introduction of water alongside this percentage of cement initially results in a stable dry density, inducing an initial ascent in the graph. Subsequent water additions lead to a gradual increase in dry density corresponding to the rise in moisture content, followed by a decline due to a higher percentage of water employed. Within this sample, the highest moisture content, coinciding with its maximum moisture content (OMC), stands at approximately 11.7%. At this moisture level, a corresponding dry density of 2.04g/cm³ is observed, as depicted in Figure 8.

<u>6% Cement:</u> The addition of water initially results in an escalation of dry density corresponding to an increase in moisture content. This trend continues until a subsequent decrease occurs due to an increase in the percentage of water utilized. The peak moisture content in this sample, representing its maximum moisture content (OMC), is observed at approximately 12.15% water, coinciding with a dry density of 2.03g/cm³, as depicted in Figure 9.

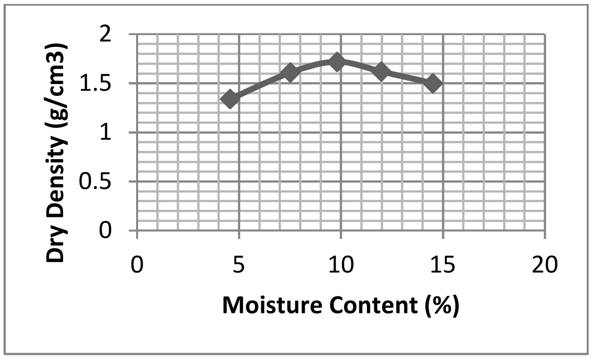

Fig 6: Graph of DD against MC (for 0% cement)

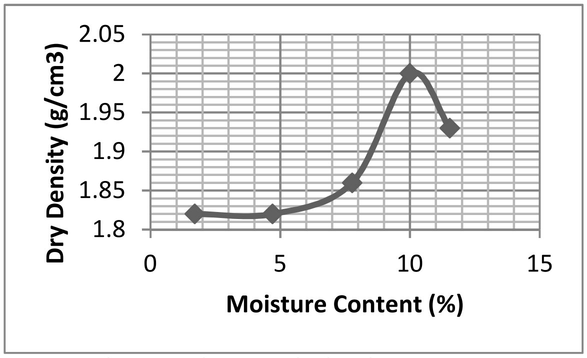

Fig 7: Graph of DD/MC (for 2% cement)

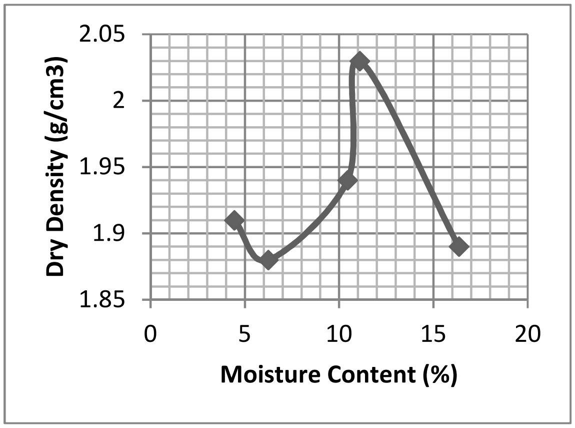

Fig 8: Graph of DD against MC (for 4% cement)

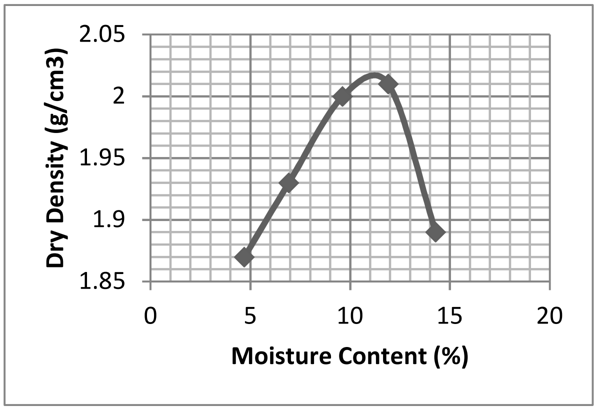

Fig 9: Graph of DD/MC (for 6% cement)

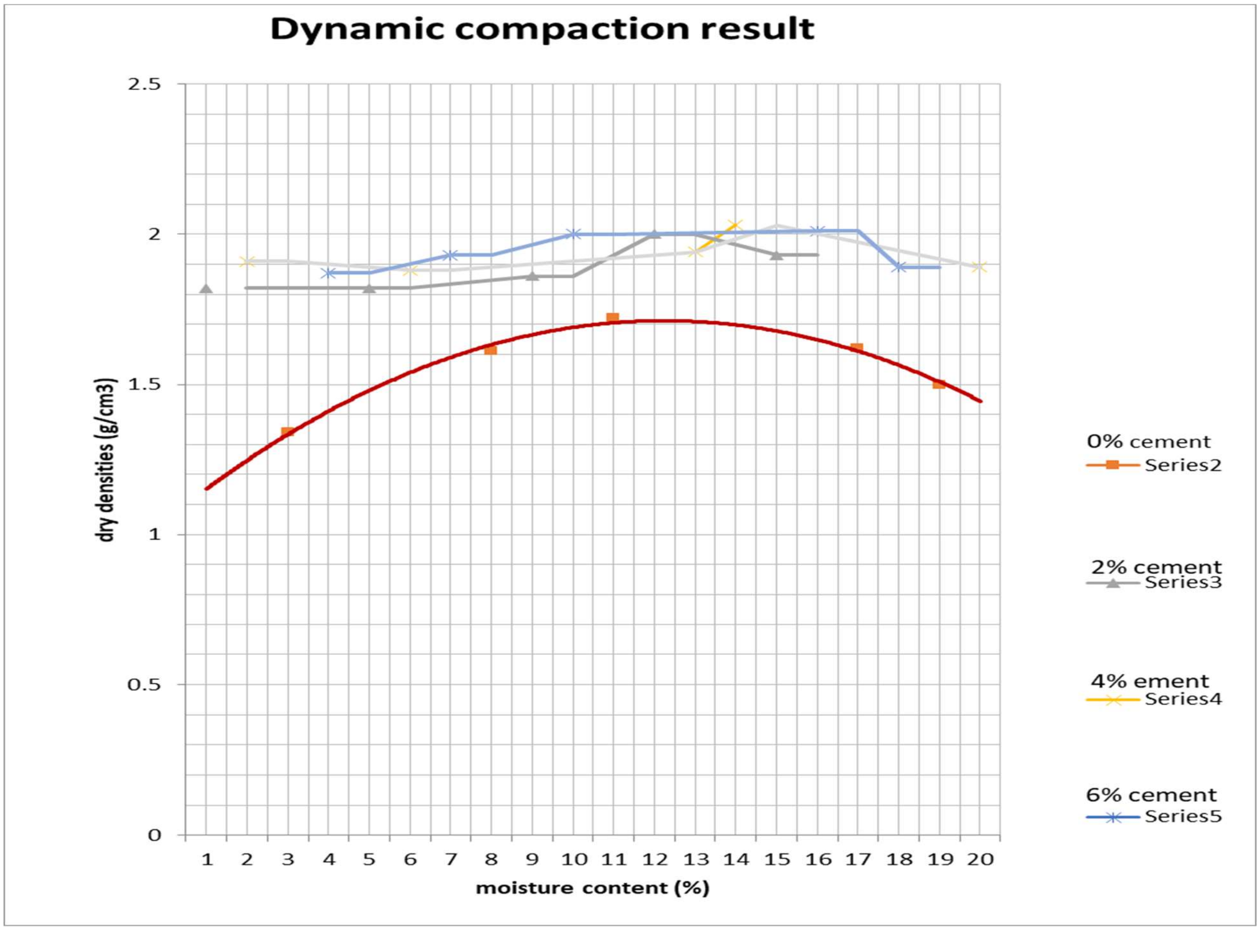

Fig 10: Graph of DD against MC FOR varying % of cement

3.4 Static Compaction Results

The study conducted tests with varying cement additions, 0%, 2%, 4%, and 6%, revealing specific masses of bulk soil for recompaction and corresponding volumes of water for each as shown in Table 1 below. The dynamic compaction test results, determining Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), guided the process of achieving a consistent soil mass for static compaction with a set water volume.

Each percentage of cement added involved replacing an equivalent proportion of bulk sand mass with cement, leading to compaction. Subsequently, the compacted samples were assessed using the California Bearing Ratio (CBR) machine.

Table 1: Static Compaction Results

Cement (%)	Mass (g)	Volume (ml)
0	3925	360
2	4564	456
4	4655	514
6	4632	532

4. CONCLUSION

The results obtained from particle size analysis indicated a predominantly sand composition with some clay and silt content present in varying amounts. The Atterberg limit tests revealed the Plastic Limit, Liquid Limit, and Plasticity Index for different cement additions. Each cement proportion led to distinct values for these limits and indices, demonstrating how the soil's behavior changed with increasing cement content. Moreover, the dynamic compaction results highlighted the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for different cement additions, revealing the soil's behavior under compaction. This comprehensive analysis achieved the study's initial goal by providing a detailed understanding of the soil's geotechnical properties and behavior under compaction.

The sample exhibits lower clay content, necessitating reduced water content for optimal compaction. Introduction of cement significantly increases the sample's liquidity, thereby modifying the inherent characteristics of the laterite. Moreover, the presence of cement accelerates the drying process compared to samples moisturized for 24 hours without cement addition. The addition of cement influences the chemical composition of the soil samples, consequently altering their geotechnical properties.

A clear distinction was noted when comparing samples with 0% cement content against those with varying cement percentages. During compaction, the initial introduction of water prompts a rapid cement hydration process, leading to an exothermic reaction absorbing approximately 32% of the water content. This initial reaction contributes to an immediate rise in the soil sample's dry density. Subsequent water additions initially decrease the dry density, followed by an increase leading to the attainment of maximum dry density.

5. RECOMMENDATIONS

Following the project's conclusion, several recommendations emerge:

a. Subgrade Suitability: The soil sample, exhibiting a liquid limit below 30% without stabilization, showcases promise for subgrade use. However, it's crucial to note that the introduction of varying percentages of cement increases the liquid limit, suggesting a need for careful consideration when applying stabilization methods.
b. Compaction Guidance: Understanding the mass of soil, particularly those with lower clay content akin to the sample utilized, allows for determining the requisite water volume for static compaction with a 2% cement additive (e.g., 4564g, 456ml). It's advised to replace 2% of the soil mass with cement, highlighting its efficacy for such soil types.
c. Moisture Management: In scenarios where soil moisture poses challenges, cement emerges as a viable solution, aiding in expedited soil drying, particularly in regions with limited sunlight or unsupportive weather conditions. The cementitious properties enhance soil strength, making it an advantageous choice for moisture control.
d. Cement as Stabilizer: Cement proves to be an excellent stabilizer, especially for laterite soils. However, it's important to note that an excessive amount of cement might diminish the soil's plasticity, influencing the optimal quantity of cement required for stabilization, underscoring the need for a balanced approach.

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