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# The Role Of Particle Size And Sorting In Natural Compaction Processes At Uwen Use Southeastern Nigeria: Insights From Sieve Analysis

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***Abstract***
*The natural process of compaction serves as the main diagenesis process which results in reduced porosity and formation of pore systems and improved mechanical properties of sedimentary basins. The process has been identified but scientists have not yet found the particular textural features which control natural geological environment compaction efficiency. The research explores how the compaction characteristics of loose sandy sediments get controlled through the particle size distribution (PSD) and sorting characteristics which develop during their deposition process.*
*The researchers performed standard dry-sieve procedures to analyze six sediment samples which they collected from various depositional environments. The study analyzed grain-size distribution curves together with various parameters which included Uniformity Coefficient ($C_u$) and Coefficient of Curvature ($C_c$) and median grain size ($D_{50}$) and fines content to assess their effects on mechanical compaction pathways. The textural element of materials affected their compaction behavior because well-graded sediments with high $C_u$ values (>5) and sigmoidal particle size distribution (PSD) curves demonstrated strong interlocking ability which allowed sand particles to move while filling empty spaces. The low $C_u$ values (~3) of well-sorted sands show steep PSD curves and high initial porosity and stable grain framework which prevents mechanical compaction while maintaining porosity during burial and diagenetic processes which lead to chemical changes including pressure solution.*
*The study found that all samples contained extremely low fine material which created evidence that clean sands will experience compaction through their sand-grade framework instead of any matrix-supported methods. The research result enables more accurate forecasting because it shows how grain-scale texture affects porosity changes with depth.*
*Sieve analysis allows researchers to identify basic sediment types through their use of this method which shows all sieve results. The study shows that PSD curve patterns together with their related coefficients act as indicators which show how well natural compaction occurs and how diagenetic processes develop. The findings directly impact reservoir quality assessment and basin modeling and shallow subsurface geotechnical evaluations because they provide a cost-efficient method which decreases uncertainty during subsurface analysis.*
***Keywords:*** *sieve analysis, PSD, compaction, sorting*

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## I. Introduction

The foundation of sedimentary basins which provides essential support for hydrocarbon exploration, groundwater management and carbon storage depends mainly on the methods used to deposit and transform sediments [1]. The most common diagenetic process that occurs in sediments requires the natural compaction process which involves both mechanical and chemical sediment volume reduction through the presence of overlying material. The main factor that causes siliciclastic rocks to lose their porosity during the initial stages of the process is compaction although people tend to discuss other methods more frequently. The process alters pore structures and impacts fluid movement and changes the physical characteristics of reservoir and seal rocks. The field of basin studies and reservoir characterization continues to experience difficulties in predicting compaction levels and its extent [2]. The outcrop sections at Uwen Use in Ibiono Ibom Akwa Ibom State was studied using granulometric analysis. It lies at latitude$5^0$18'21.87 N and Longitude $7^0$49'0.53 E.

Engineers have researched earth material compaction since the early days of geotechnical engineering to discover ways of achieving maximum dry density for construction through the use of dynamic loads. The natural process of compaction occurs throughout millions of years when constant pressure from overlying sediments creates pressure on buried materials which depend on specific sediment characteristics. The two main characteristics of deposition which create essential features are particle size distribution and sorting. The two elements control how grains initially arrange themselves which creates contact points and empty areas between adjacent grains. The initial structure of the sediment determines how it behaves under burial pressure as it decides between two burial processes which either lead to quick porosity loss through grain movement or maintain porosity until chemical processes become dominant [3].

The study of sediment texture lacks sufficient research which connects standard grain-size measurements to precise estimation of actual ground compaction. Sieve analysis serves as a fundamental technique in sedimentology and geotechnical engineering which generates precise grain size distribution curves and calculates essential parameters including the uniformity coefficient Cu and the coefficient of curvature Cc. Engineers classify materials by using these data for practical links while geologists examine the information to understand past environmental conditions. PSD serves as a genetic fingerprint in few studies which can predict the changes that occur during diagenesis. The research studies need to explore how specific PSD patterns and sorting measurements impact porosity reduction efficiency during burial processes [2][4].

This research investigates the connection between particle size, sorting, and natural compaction through analysis of sieve data. The study advances the idea that natural compaction occurs according to the level of sediment texture development which exists in the sediment at the moment of its deposition. The research will investigate these particular hypotheses.

1. Well-graded, poorly sorted sediments will demonstrate increased compactability because their loading process results in the formation of a more stable and denser grain structure.
2. The uniformity coefficient ($C_u$) and coefficient of curvature ($C_c$) serve as predictors for sediment test results which show how sediments will respond to mechanical porosity reduction.
3. The fines content which measures less than 0.063mm defines two essential functions because it acts as a pore-filling material which boosts density to its peak value and restricts the compaction process when present in excessive amounts.

The detailed sieve analysis was used to evaluate hypotheses through examination of unconsolidated sediment samples which were collected from various depositional environments. The study goes beyond basic classification by performing a quantitative assessment of the grain-size distribution curves and their corresponding parameters which the research generated. The research examines the textural signature which each sample possesses to determine their potential for evaluating both depositional energy and process and expected compaction sequence.

The research holds significance because it achieves two principal objectives. The first objective provides a practical and cost-effective method for assessing the diagenetic potential of subsurface sands, even when only a few core or outcrop samples are available. The second objective establishes a direct connection between sediment sources and their physical changes, which enhances our comprehension of early diagenesis. The process of estimating porosity loss through the analysis of fundamental grain characteristics has become more important because accurate resource evaluation needs precise dietary assessment. The research results present grain-size measurements which the study uses to explain sedimentary processes while demonstrating their effect on porosity estimation and sedimentary basin changes.

## II. Literature Review

### The Geological Framework of Compaction

Natural compaction processes create changes to sediments which start after their initial deposition and continue through their later burial stages. The first studies showed that sediment porosity decreases with depth because compaction acts as the main process which reduces pore space. The research that followed identified two types of compaction processes which operate at different depths and temperature conditions. Siliciclastic rocks employ mechanical compaction as their main method for porosity reduction which occurs at shallow and moderate burial depths [5][6].

The characteristics of sediments determine how compaction processes will develop. Research has demonstrated that the behavior of compaction depends on four key factors which include grain size and shape and sorting and packing. The depositional environment and hydrodynamic conditions establish these textural attributes which create a strong connection between initial porosity and compaction style and the original sedimentary environment [5].

### Sedimentological Controls: Grain Size Distribution and Sorting

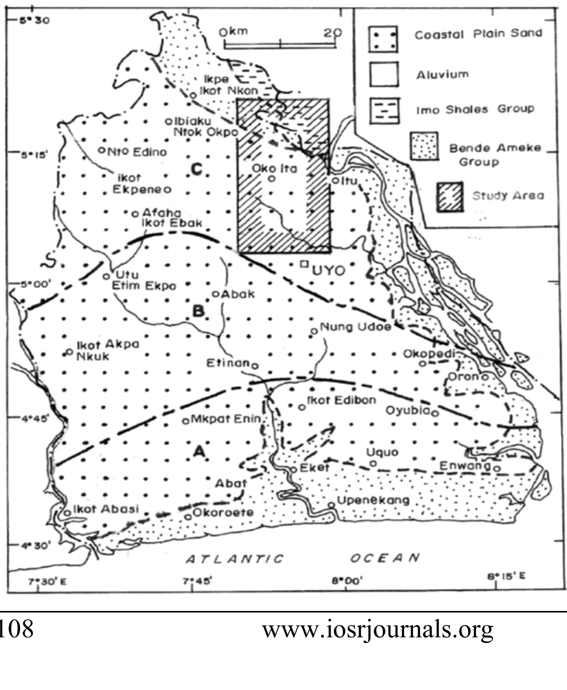
The study of particle size distribution (PSD) enables researchers to identify the different types of sediment materials present at a particular location. The Folk and Ward methods provide a quantitative tool for measuring grain-size parameters which include mean grain size and sorting and skewness and kurtosis. The sorting parameter holds special importance because well-sorted sands which form in high-energy dune and beach environments show their greatest initial porosity through their open and consistent grain patterns.

The engineering concept of the **Uniformity Coefficient** ($C_u$) and **Coefficient of Curvature** ($C_c$), derived from sieve, finds a direct geological analogue in sorting statistics. The presence of high $C_u$value indicates that active environments such as river channels and turbidite lobes contain poorly sorted sediments. The study results demonstrate that actual burial conditions cause the sediments to lose porosity because fine grains fill the spaces between larger grains and create a dense structure which resists further compaction. Another researcher found that adding a small amount of ductile fines (5-15%) can improve mechanical compaction by facilitating grain movement and adjustment. The presence of excessive fines results in sediment that changes from being supported by grains to being supported by the matrix. The primary element that determines the mechanical and hydraulic behavior of clay-rich sands and sandy mudstones is their compressible clay matrix which functions as the main element for compaction [8].

The detrital clay content which depends on the depositional environment, functions as a crucial determinant for early porosity loss during compaction according to the study [7]. Researchers have conducted studies to create methods that connect two different academic disciplines which contain separate areas of study. [9] The authors demonstrated that modern analogues can be used to derive PSD parameters which subsequently model sandstones reservoir quality evaluation. The authors used machine learning techniques to create a link between grain-size statistics obtained from well logs and actual porosity measurements which enabled them to factor in compaction impacts. The existing literature lacks a comprehensive study which examines sieve curve behavior through process-based methods that treat the curve shape and derived coefficients and fines content as separate elements that affect natural compaction efficiency. The study aims to fill this research gap through the establishment of sieve analysis as a diagenetic process prediction tool instead of its traditional role as a classification instrument [10].

## III. Geology Of The Study Area

Benin formation also known as coastal plain sands the lithologies includes lateritic layers,thick sequences of clays,sands sandstones and gravel beds with pebbly sands commonly exposed on hillsides,roadcuts and stream channels. Generally the sands in this area are mature,coarse and moderated sorted. The area falls within the Benin Formation in the Niger Delta basin (Figure 2). This formation constitutes mainly of sand stones which makes up 90% of it and it stretches from the west through the Niger delta and extends up north towards part of the Anambra basin where it transverses to the Mamu Formation. The sandstone of this Formation is also intercalated with shale units and there is poor sorting of the unit grains which include the fine sand, coarse sand, sub angular to well-rounded pebbles, gravels and the angular cobbles units. The presence of light streak and wood fragments suggests that they are mainly of continental deposit of upper deltaic environment. The variability of the shallow water deposition is indicated basically by most structural units that could be spotted within the Benin Formation. The thickness of this Formation ranges from about 6000ft and above. Just little collection of hydrocarbon could be found within this Formation. In addition to a surface formation the Benin Formation crops out widely at surface across the delta province. The sand and sandstone are poorly sorted, and partly unconsolidated white or yellowish brown.



## IV. Methodology

**Sample Acquisition and Site Selection**

The researchers collected samples from six different sites which contained unconsolidated sand materials. The researchers studied natural sediment texture patterns by using different sampling sites which each offered a unique environmental setting.

- **Selection Criteria:** The researchers selected locations by using surface geology maps and conducting field surveys to identify areas with modern or Quaternary sediment deposits. The team preferred sites which contained river cuts together with pits because these sites enabled them to access unspoiled materials which had not yet experienced weathering or human disturbance.
- **Sampling Protocol:** At all research sites scientists extracted sediment samples from the same depth range which extended between 0.5 meters and 1.0 meters below ground level. The process protected the samples from contamination because roots and oxidized soil materials were prevented from entering the testing area. The research team used a stainless-steel shovel to gather samples which they placed into labeled plastic bags for laboratory transport to maintain sample integrity by preventing moisture and contamination.

**Laboratory Procedure: Sieve Analysis**

The dry mechanical sieve analysis method was used to measure the grain size distribution for each sample.

**Sample Preparation**

1. **Oven-Drying:** The bulk sample underwent drying in an oven which maintained a temperature of **105 ± 5 °C** temperature range for a duration of 24 hours until all moisture content was eliminated.
2. **Quartering and Splitting:** The dried sample was used to produce a test portion of 500 to 700 grams through **a riffle splitter which enabled testing of the complete sample using its chosen segment.**

**Sieving Process**

1. **Sieve Stack Assembly:** The researchers constructed their sieve stack using brass sieves which they arranged in order of their decreasing mesh size. The stack used in this study included these sizes (mm): **16.0 5.6 4.0 2.36 1.18 0.850 0.600 0.425 0.300 0.150 0.063** and a bottom pan.
2. **Mechanical Shaking:** The researchers placed the representative sample on the top sieve which they secured to a **mechanical sieve shaker** that operated for **15 minutes** to achieve complete sample separation.
3. **Weighing:** The analytical balance measured the weight of material which remained on each sieve and in the pan to an accuracy of **0.01 grams.**

**Data Processing and Parameter Calculation**

The raw mass data processing produced cumulative grain size distributions together with essential interpretative parameters which were computed from the data.

**Calculation of Percentages**

For each sieve size, the following were calculated:

- **Percent Retained (%R):** $\%R_i = (M_i/M_{total}) \times 100$
- **Cumulative Percent Retained (Σ%R):** The running total of %R from the coarsest sieve downward.
- **Percent Passing (%P):** $\%P_i = 100 - \Sigma\%R_i$

**Derivation of Key Grain Size Parameters**

The critical diameters were obtained through graphical interpolation from the cumulative passing curve.

- **Effective Size ($D_{10}$):** The sieve size through which 10% of the sample passes.
- **$D_{30}$ & $D_{60}$:** The sieve sizes through which 30% and 60% of the sample pass, respectively.
- **Median Grain Size ($D_{50}$):** The sieve size through which 50% of the sample passes.

**Calculation of Geotechnical Indices**

The derived diameters were used to calculate two fundamental coefficients that describe how distribution shapes.

- **Uniformity Coefficient ($C_u$):** $C_u = D_{60}/D_{10}$
- **Coefficient of Curvature ($C_c$):** $C_c = (D_{30})^2/(D_{60} \times D_{10})$

**Determination of Fines Content**

The **percentage of fines** (silt and clay fraction) was defined as the percentage passing the 0.063 mm sieve:

$$Fines\ Content = \%P_{0.063\ mm}$$

## V. Results, Interpretation, And Discussion

The sieve analysis results demonstrate how particle size distribution together with sorting patterns actually influence the development of natural compaction processes. The research examines grain-size distribution curves and effective grain-size parameters and sorting indices and fines content. The three parameters provide essential information which explains how soil material compacts when natural forces and external weights are applied.

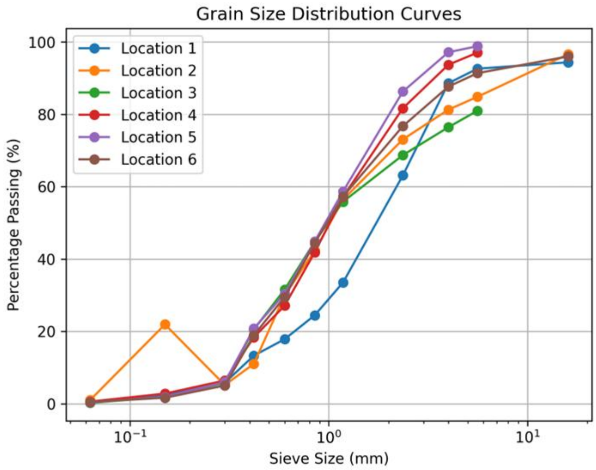



**Figure 4.1: Grain Size Distribution Curves**
The grain size distribution curves show that the soils are mainly composed of sand-sized particles which exhibit different levels of sand distribution. The broad curves show that better packing potential exists which results in increased compaction efficiency.

The grain size distribution curves indicate that the sampled locations contain mostly sand-sized soils which display various degrees of sand-sized soil distribution. The locations display broad, gently sloping curves which show that they contain multiple particle size ranges. The well-graded soils demonstrate high packing capacity because the smaller particles can fill the gaps between the larger particles which creates a compact and interconnected system.

The locations with steep, narrowly concentrated curves show that the soils have uniform particle distribution with particles that maintain consistent size. The soils maintain larger void spaces because they contain grains of similar size which prevents proper filling of interstitial areas which leads to their inefficient compaction. The materials exhibit higher compressibility because natural overburden causes them to experience long-term settlement.

The grain size curves demonstrate that the gradation pattern determines compaction behavior because well-graded soils enable efficient void reduction and create stable fabric structure, while uniformly graded soils maintain open spaces which result in weaker structural integrity.

**Effective Size Parameters and Sorting Coefficients**

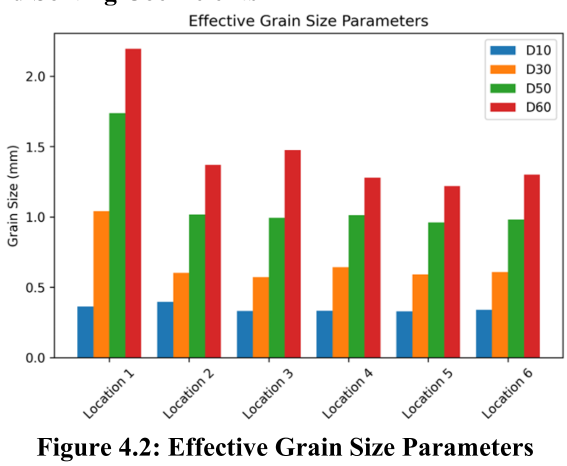



**Figure 4.2: Effective Grain Size Parameters**
The effective grain sizes (D10 D30 D50 and D60) control three processes which include pore collapse and particle skeleton formation and energy transmission during compaction.

Researchers need the effective grain size parameters because they show how soil skeletons react to compactive stress through their distribution patterns which the curves depict.

- The function of D10 as an effective size measurement determines its ability to measure permeability and drainage efficiency. The smaller D10 values lead to slower pore water dissipation which results in consolidation-dominated compaction. The material with larger D10 values supports quick drainage which results in faster densification.
- The D30 and D50 sizes represent intermediate and median sizes which define the main load-bearing elements of the system. The proportions of the materials determine both the particle rearrangement process which occurs during stress and the capacity of the soil fabric to collapse into a denser state.
- The D60 value from testing reveals the quantity of large particles which constitute the fundamental structural components of the material.

Locations in which these parameters show continuous growth from D10 through D60 display equal proportions of fine particles and medium particles and coarse particles. The soil maintains its capacity to transmit stress because the two elements establish an optimal balance which leads to pore space collapse and strong compacting of the soil. The sudden changes that occur between these parameters demonstrate that distribution patterns experience interruptions which result in packing difficulties.

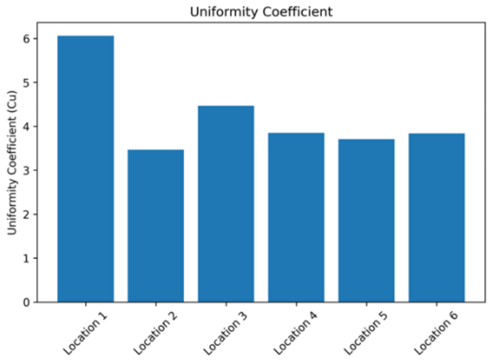



**Figure 4.3: Uniformity Coefficient**

The presence of higher uniformity coefficient values indicates the existence of well-graded soils which demonstrate better compaction abilities because they effectively fill their empty spaces between particles.

The uniformity coefficient ($C_u$) serves as a fundamental metric that evaluates both the sorting and the gradation of materials. Soils display their full range of particle sizes through their high $C_u$ values whereas low $C_u$ values show that the material has either a uniform distribution of particle sizes or a poor grading system.

The compacting process of soils improves when their $C_u$ values increase because different particle sizes create better void filling and interlocking solutions that need less energy for rearrangement.

The soils develop dense layers which produce mechanical stability that endures actual loading conditions. The soil structure shows less compaction resistance because low $C_u$ values indicate the presence of uniformly graded soils. The limited particle size range of the materials leads to two outcomes: it prevents the formation of voids and this results in reduced efficiency of compaction and increased risk of settling. The $C_u$ measurement serves to identify locations which demonstrate high compaction potential and areas which exhibit limited densification capacity.

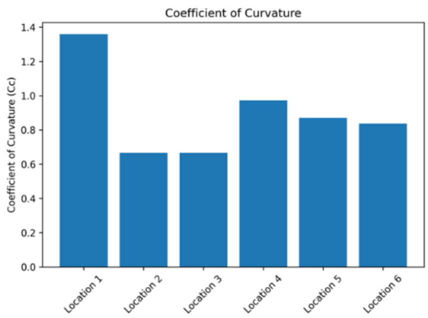



**Figure 4.4: Coefficient of Curvature**

The coefficient of curvature values demonstrates two material properties which include the continuous flow of grain size distribution through various particle sizes and the efficiency of material packing.

The coefficient of curvature ($C_c$) provides additional information to $C_u$ by measuring how smoothly and continuously grain size distribution disperses throughout the material. Well-graded sands display their typical range of particle sizes between 1 and 3 which demonstrates that sufficient intermediate particle sizes exist to establish a link between coarse and fine fractions.

Locations with good $C_c$values display continuous particle size distribution which improves packing efficiency while decreasing material strength defects. The distribution becomes discontinuous when Cc exceeds this range because it either fails to present intermediate sizes or presents sizes in an unorganized manner. The presence of a high $C_u$ value does not guarantee good compaction because an unfavourable $C_c$ value indicates that specific size ranges have low representation which affects compaction efficiency.

$C_c$ enables evaluation of soil gradation which determines whether it creates a stable interlocking structure or whether it has discontinuities that block optimal compaction.

**Fines Content and Its Implications**

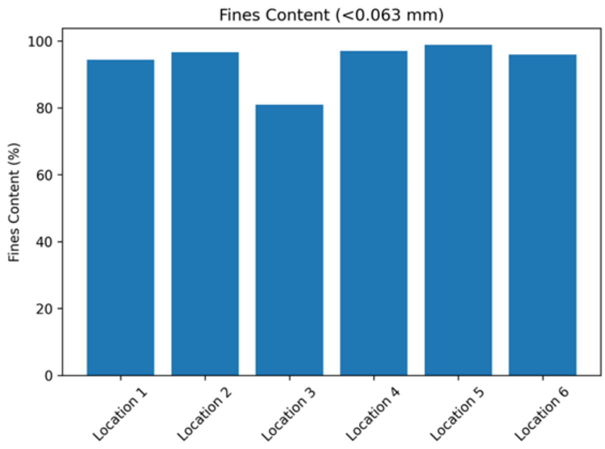



**Figure 4.6: Fines Content**

The content of moderate fines content produces better compaction results because it allows particles to move freely while using less energy for the process.

The fines content results from different locations show substantial differences because most sites exhibit extremely high fines content which constitutes about 95% of their total material. One location (Location 3) shows a lower value which measures at approximately 80%.

Fine content plays a nuanced but critical role in compaction:

• Compaction is enhanced by fine material from Location 3 which has moderate fine content because it decreases friction between particles while allowing their movement through the material. The process leads to higher dry densities and better packing efficiency.

• The presence of excessive fines material, which is observed at other sites, leads to challenges that hinder compaction work. High fines content causes water retention and energy absorption during compaction and slow drainage, which results in compaction process changes from particle movement to gradual material compacting through time.

The required balance between fines used to fill voids and their actual required proportion needs to be maintained. The excessive presence of fines results in two detrimental effects which cause reduced material compaction efficiency and prolonged time for natural environments with limited drainage to reach their consolidated state.

**Integrated Interpretation: Linking Particle Size, Sorting, and Natural Compaction**

The complete understanding of natural compaction processes needs researchers to study all parameters which investigate how particle size and sorting impact the process.

• Well-graded soils achieve their highest compaction efficiency because their structural variations enable them to fill voids and interlock particles successfully.

• Well-graded soils achieve their highest compaction efficiency because their structural variations enable complete void space filling and particle interlocking.

• The compacting efficiency of uniformly graded soils with low $C_u$ values and steep grain size curves is decreased while their long-term settlement tendency is increased.

The sieve analysis results demonstrate that natural compaction processes rely on two primary factors which are particle size distribution and particle sorting methods. Soils with broad gradation and continuous gradation and balanced fines content develop dense stable layers when subjected to geological loading. The two effects that occur in poorly graded and well-graded soils result from their decreased compaction efficiency and increased compressibility.

## VI. Conclusion

The research employed sieve analysis as its primary method to investigate how particle size distribution together with sorting methods affects the natural compaction process. The study found that soil grain size characteristics serve as the primary factors which determine soil behavior under geological loading conditions and during pore collapse and long-term densification. The sampled locations show an established pattern which shows that the combination of gradation and effective grain sizes and sorting indices and fines content controls soil compacting abilities. The grain size distribution curves provided the first indication of compaction potential which showed the difference between well-graded soils that contained high packing efficiency and uniformly graded soils that had limited void-filling capacity.

The effective grain size parameters (D10, D30, D50, D60) which defined the soil matrix structure exhibited that balanced proportions of fine, medium, and coarse particles enable optimal stress transmission together with pore collapse. The soil sorting indices which include the uniformity coefficient ($C_u$) and coefficient of curvature ($C_c$) became crucial tools for identifying soils that possess continuous well-graded distributions which can create dense interlocked structures through natural compaction. The presence of acceptable content emerged as a critical modifier of compaction behaviour. The presence of moderate fines helped particles to rearrange and fill voids while excessively high fines shifted the compaction mechanism toward slower, consolidation-dominated processes.

The understanding of long-term settlement patterns requires this distinction because natural environments experience compaction at rates which depend on drainage and pore pressure dissipation. The research demonstrated that particle size distribution together with soil sorting functions as active elements which determine natural compaction efficiency rather than existing as passive soil characteristics. Well-graded soils which show optimal sorting characteristics and maintain balanced fines content create stable dense layers under geological loading conditions, whereas soils with poor grading or excessive fines will experience reduced compaction efficiency and higher settlement risks.

The insights present vital information which affects geotechnical assessment together with sedimentological interpretation and groundwater studies because they show how soil structure and compaction behaviour affects subsurface stability and permeability and long-term mechanical performance.

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