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ANALYSIS OF QUARRY MATERIAL CHARACTERISTICS IN RECLAMATION WORK USING SAND CONE AND CBR METHODS (CASE STUDY: PATIMBAN PORT PACKAGE 5)

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ABSTRACT
Soil compaction is an important process in reclamation work because it has a direct effect on the carrying capacity and stability of the structure built on it. This study was conducted in one of the specific work zones of Area C1a in the Patimban Port reclamation project, where sand material from various quarry sources is used, each having different physical characteristics that can affect the success of compaction. This study aims to analyze and compare the results of material compaction from four different quarries using the field density test (*sand cone*) and laboratory carrying capacity test (CBR) methods. The research methodology includes the analysis of physical characteristics such as particle size distribution and *sludge* content, as well as compaction quality testing after applying the same number of vibratory roller passes to each material. The results showed that the material from Quarry A achieved the highest average field density (104.71%), indicating the highest compaction effectiveness among the materials tested. In terms of carrying capacity, the material from Quarry B proved to be the most superior, with the highest CBR value both in dry conditions (103.00%) and after submersion (58.00%). In contrast, the Quarry C material showed the highest sensitivity to water, as its CBR value decreased from 75.00% to 27.00% when submerged, which correlated with the highest silt content (9.21%). These findings demonstrate that the physical characteristics of materials, such as silt content and grain size distribution, are the main determining factors affecting the final yield of soil density and carrying capacity. This research provides technical recommendations for selecting reclamation materials to ensure the achievement of compaction quality targets that align with project conditions and needs.

Keywords: Reclamation, Material Characteristics, Soil Density, Soil Bearing Capacity, Sand Cone, CBR.

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INTRODUCTION

Reclamation is one of the methods used to expand land by dredging water areas using reclamation materials. The reclamation process is generally applied in infrastructure development such as ports, industrial estates, and coastal settlements (Feng et al., 2019; Gerwing et al., 2022; Kanchanapiya & Tantisattayakul, 2022; I. E. Setiawan et al., 2021; Zhang et al., 2020). The success of reclamation depends not only on the volume of reclamation but also on the quality of compaction and the carrying capacity of the reclaimed soil. According to Ikbal and Zhafirah (2022), optimal soil density is essential, and a stockpile can be said to be solid if it meets the minimum density degree requirement of 95%. This criterion reflects the prevailing industry standards in Indonesia, where similar requirements are formally set out in the 2018 General Specification (Directorate General of Highways, 2020). Fulfillment of these strict density criteria is a prerequisite before proceeding to the next construction work.

The selection of sand material greatly affects compaction results. Factors such as grain size distribution, silt content, and optimum moisture content greatly influence the interaction between materials and compaction machines. Research Saputra et al., (2025) shows that mixing *C* excavated sand in soft soils can increase soil density and significantly improve compaction characteristics.

Soil compaction can be evaluated through a field density test (*sand cone* test) and a California Bearing Ratio (CBR) test to determine the bearing strength of the soil. According to Hayadi, Lakawa, and Sulaiman (2021), the durability or stability of construction is greatly influenced by the quality of the subbase layer—the higher the level of soil density and carrying capacity, the stronger the structure built on it. Therefore, the selection of quarry materials from different quarries needs to consider physical characteristics such as particle size distribution and silt content. Research Amri, Rustamaji, and Priadi (2022) shows that compaction energy and CBR values in soft soils are greatly influenced by the composition of the sand mixture, where the right sand content significantly increases the effectiveness of compaction and bearing strength (CBR).

In reclamation work, heavy equipment such as the Vibratory Roller is often used because it is able to generate vertical dynamic forces to increase the density of the material of the excavator. However, the effectiveness of compaction is not only determined by the type of tool and the trajectory pattern but also by the characteristics of the material (Arum Pratiwi & Priyanto, 2022; Fitri Yadi & Priyanto, 2023a, 2023b; Tri Febriantoro & Priyanto, 2023; Yadi et al., 2023). Some studies show that, with the same number of compaction trajectories, materials with the right texture and moisture content are easier to compact optimally. Lubis, Kumalasari, and Nurdin (2022) found that the more compaction trajectories, the percentage of *binder course* layer density tends to increase—for example, from 98.34% (14 trajectories) to 99.84% (18 trajectories).

Based on these conditions, this study was conducted to analyze how the physical characteristics of materials from various quarries affect the final result of compaction quality, which is evaluated through field density and soil carrying capacity tests.

METHODOLOGY

This study uses a quantitative method with a comparative study design to analyze the influence of material characteristics on compaction quality in a case study of reclamation work. Research workflow. starting from problem identification to drawing conclusions, is systematically summarized in Figure 1.

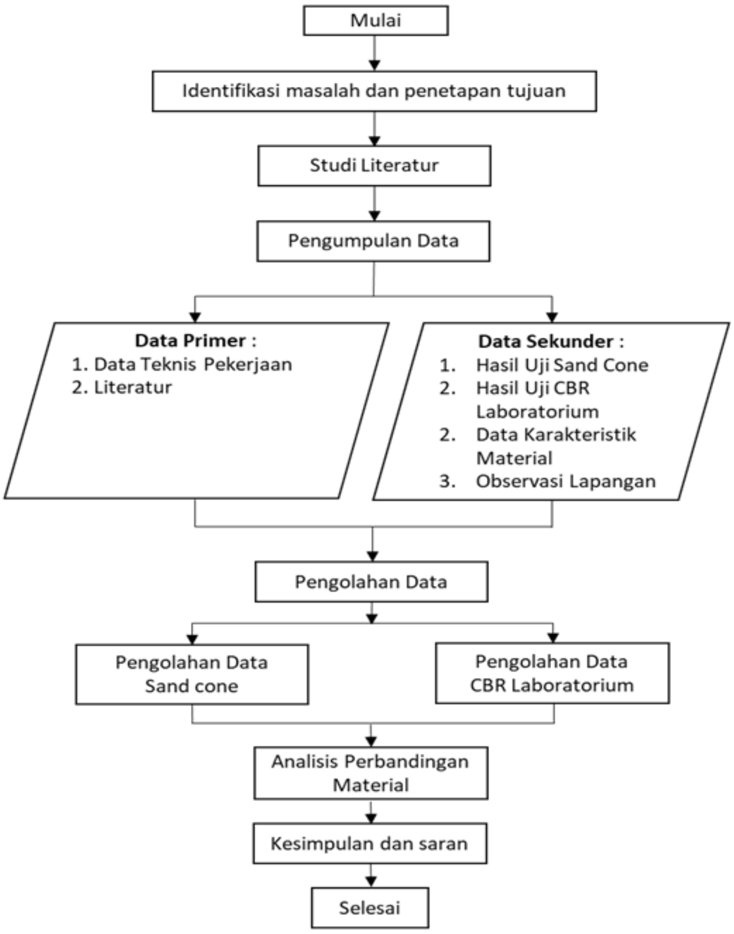


Figure 1. Framework

The case study was conducted on the Patimban Port Reclamation Project Package 5, Subang, Indonesia. Specific data collection was focused on Area C1a, which is one of the main working zones in the project. Area C1a is visually shown as a shaded section on the following location plan, as presented in Figure 2.

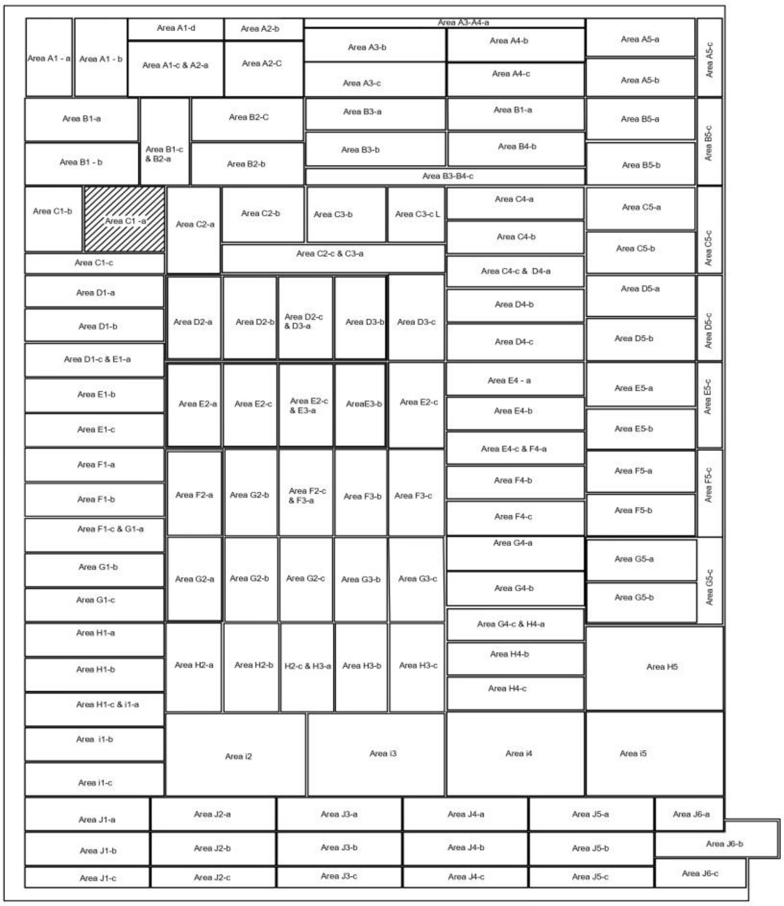


Figure 2. Area Plan C1a (Shaded area)

The independent variable is the extraction material derived from four different quarries, which, to maintain the principle of confidentiality, are referred to in this study as Quarry A, Quarry B, Quarry C, and Quarry D. The dependent variable is the compaction quality, measured through two parameters: (1) field density value (%) and (2) soil carrying capacity value (CBR%). The control variable applied uniformly is the use of one type of compactor (*Vibratory Roller*) with eight compaction trajectories for each material.

Quality testing procedures are carried out based on applicable standards. The field density test using the *Sand Cone* method refers to the ASTM D1556 standard, while the soil carrying capacity test uses a laboratory CBR test in accordance with SNI 1744:2020. The collected data are then analyzed descriptively and comparatively to compare the performance of each material. The quality acceptance criteria are based on project standards referring to the 2018 General Specification for Road and Bridge Construction Works (Directorate General of Highways, 2020), which stipulates that the field density should be ≥ 95% of the laboratory's maximum dry density (MDD) value.

RESULTS AND DISCUSSION

The results of the soil density and carrying capacity test are presented based on the order of the heap layers in the C1a area. To evaluate the influence of material characteristics. The test was carried out on eight layers that were sequentially using materials from four different quarries. as illustrated in Figure 3.

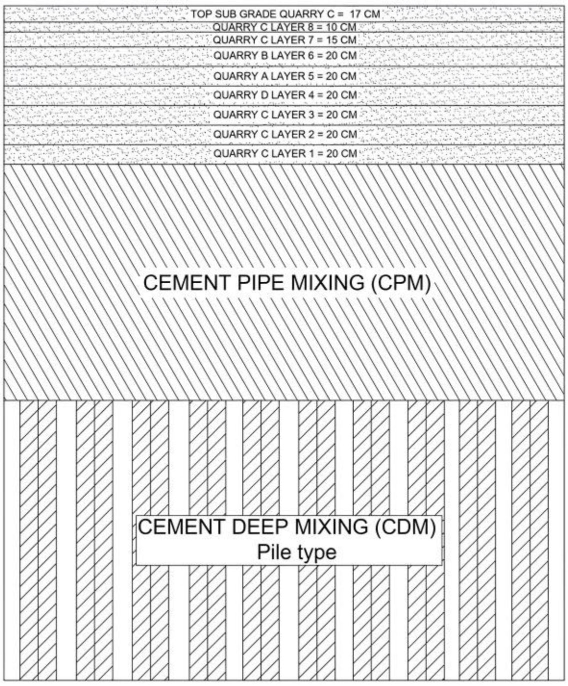


Figure 3. Cross-section of the Reclamation Backfill Layer

Figure 3 above shows the scheme of eight layers of reclamation management that is the object of the research. Sequentially from the base layer Cement Pipe Mixing (CPM) is a structure of the backlog layer consisting of materials sourced from four different *quarries*. The first three layers (Layers 1–3), each 20 cm thick, use material from Quarry C. The next layers are Layer 4 (20 cm) from Quarry D, Layer 5 (20 cm) from Quarry A, and Layer 6 (20 cm) from Quarry B. For the top layer, the material from Quarry C is again used to form Layer 7 (15 cm). Layer 8 (10 cm), and *sub-grade top layer* (17 cm).

1. Field Density Test Results (Sand Cone Test)

Sand cone testing was carried out on each layer of quarry layers, each of which used material from a different quarry source, namely Quarry A, Quarry C, Quarry B, and Quarry D. Compaction was carried out with eight passes using Vibratory Roller-type heavy equipment. The results of the sand cone test showed that there was a variation in the average value of field density between the quarry materials, which reflected significant differences in physical characteristics, especially the grain distribution and silt content of each quarry.

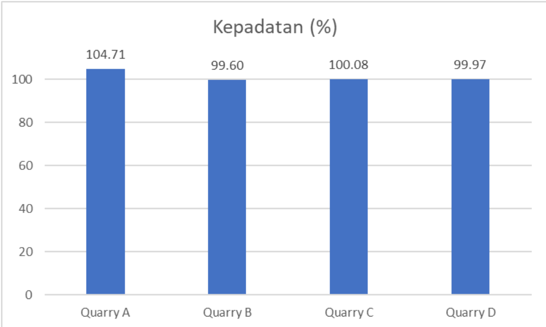
Table 1. Sand Cone Test Results

Quarry	Density (%)	Stability
A	104.71	Highly Stable
B	99.60	Stable
C	100.08	Stable
D	99.97	Stable

The test results table showed that the material from Quarry A recorded the highest field density of 104.71%, which indicates the most effective compaction performance compared to materials from other quarries. The material from Quarry B shows an average density of 99.60%. Furthermore, Quarry C has an average density of 100.08%, while Quarry D records a value of 99.97%. All materials tested successfully exceed the required density standards and are in the stable category.

These findings reinforce that physical parameters such as grain size distribution and silt content have a dominant influence on compaction results. Materials with low silt fractions and coarse sand dominance are more responsive to the vibrational forces of the Vibratory Roller. This is in line with the findings of (Saputra et al. n.d. 2025) which state that variations in texture and material composition significantly improve compaction efficiency, thereby supporting the long-term stability of the structure on it.

Diagram 1 Comparison of Average Field Density of Each Quarry



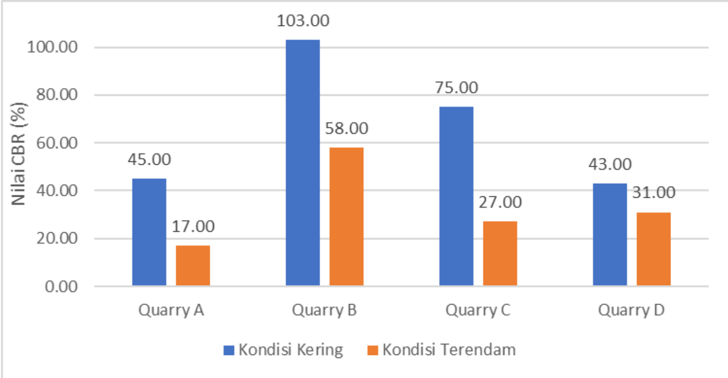
2. Soil Bearing Capacity (CBR) Test Results

Table 2 Laboratory CBR Test Results

Quarry	CBR Dry Conditions (%)	CBR Submerged Condition (%)
A	45.00	17.00
B	103.00	58.00
C	75.00	27.00
D	43.00	31.00

Table 2 shows the results of laboratory CBR tests on four different types of quarry materials under two conditions: unsoaked and post-soaking. In the unsoaked condition, the material from Quarry B recorded the highest CBR value of 103.00%, followed by Quarry C (75.00%), Quarry A (45.00%), and Quarry D (43.00%). However, after soaking, there is a decrease in the CBR value of the entire material. Quarry B material maintains the best bearing capacity performance in water saturated conditions (58.00%), showing high resistance to moisture. In contrast, Quarry C material underwent the most drastic power degradation, indicating that high silt levels (9.21%) played a role in weakening the interparticle structure when submerged. Meanwhile, the value of CBR Quarry D dropped to 31.00% and Quarry A to 17.00%. These results indicate that the material from Quarry B has the most moisture-stable characteristics, making it a superior choice for use in reclamation or subgrade areas with high potential water saturation.

Diagram 2 Comparison of Laboratory CBR Values



3. Effect of Material Characteristics on Compaction.

Table 3 Influence of Material Characteristics

Parameters	Quarry A	Quarry B	Quarry C	Quarry D
D100	9.50	19.00	10.00	19.00
D20 (mm)	0.60	0.70	0.29	2.00
Wetlands and Clay %	4.97	6.96	9.21	5.61
Optimal Moisture Content (%)	6.20	5.60	4.65	5.60

Table 3 shows the characteristics of Quarry A material that supports the compaction performance, including the low silt content of 4.97%. The distribution of grains is dominated by coarse sand fractions. and an optimal moisture content of 6.20% which is relatively close to the actual moisture content in the field. This combination of physical properties allows Quarry A materials to respond more effectively to machine vibrations and consistently produce high density.

This is in line with findings in a study by (I. A. Setiawan, 2023) which shows that the interaction between soil characteristics (such as optimal moisture content and material type) and the vibrational energy of the compactor greatly determines the achievement of uniformity and optimal density quality.

4. Technical Implications and Recommendations

Based on the results of the analysis, several technical implications and recommendations can be conveyed as follows:

- The material from Quarry A showed the highest compaction response. Therefore. This material is recommended for use in top layers or reclaimed areas that demand the achievement of high density effectively.
- For structural layers that require the highest bearing capacity and stability, especially in areas with water saturation potential. The material from Quarry B is the best choice. This is based on its superior CBR value, both in dry (103.00%) and submerged (58.00%) conditions. In contrast, Quarry C material is not recommended for wet areas due to its drastic decrease in strength when submerged in water.
- The selection of urugan material must consider the balance between ease of compaction and saturated carrying capacity. Quarry A material excels in terms of ease of compaction. while

Quarry B showed the best performance in terms of post-immersion strength. The integration of the two can result in optimal reclamation performance.

CONCLUSION

Based on the results of tests and analysis on reclamation compaction work, it can be concluded that the physical characteristics of the material greatly affect the yield of soil density and carrying capacity. Materials from Quarry A showed the best compaction response by achieving the highest average field density (104.71%), which was caused by the lowest silt and clay content (4.97%). However, in terms of carrying capacity, Quarry B material proved to be the most superior, with the highest CBR value both in dry conditions (103.00%) and when submerged (58.00%), making it the most reliable material for structural layers. In contrast, Quarry C material showed the highest sensitivity to water due to its highest *silt* content (9.21%), causing the CBR value to drop significantly from 75.00% when dry to 27.00% when submerged. The negative correlation between high silt levels and the plummeting CBR value is supported by fundamental findings from other studies. For example, a study by Rahmanto and Wulandari (2020) also concluded that the percentage of clay and silt has a direct influence on carrying capacity, where the smaller the content, the greater the CBR value obtained. This confirms that silt levels are a key parameter determining the carrying capacity performance of reclaimed materials. Meanwhile, Quarry D material showed more moderate carrying capacity performance, with a better submerged CBR value (31.00%) than Quarry C.

These findings are in line with the results of the study by Wardani et al. (2023), which show that silt content and sand grain distribution significantly affect the CBR value of the soil. The highest value is obtained at the optimum moisture content, confirming the important role of material characteristics in achieving effective and uniform compaction results. Therefore, the selection of reclamation materials needs to consider the maximum density and carrying capacity of saturated soil. Adjustment of the moisture content to the optimum value for each granular material is also important to achieve the maximum CBR value, as evidenced in research by Rinaldy Rizky A. Lubis, Darlina Tanjung, and Anisah Lukman (2024) on *Granular Selected* materials in the Indrapura–Kuala Tanjung Toll Road project. The combination of selecting suitable materials and proper regulation of moisture content supports the achievement of compaction quality targets and improves the overall quality of work.

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