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THE INFLUENCE OF DIVERSE SUBSTITUTIONS FOR FINE AGGREGATE ON CONCRETE STRENGTH IN THE REDUCTION OF NATURAL RESOURCES RELIANCES

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Abstract

Enhancing concrete strength has become increasingly imperative within the construction sector. The primary aim of this study is to assess the performance of concrete casting using laterite and coastal sand individually. The adoption of alternative soil in concrete casting is imperative as it can reduce reliance on river soil. The laterite soil utilized in this study is sourced from Bukit Chabang, Perlis, while the coastal sand is obtained from Kuala Perlis. The optimal replacement percentages for laterite and coastal sand are recorded at 15% and 20%, respectively. It is observed that a 25% increase in concrete strength is achieved with a 20% replacement of coastal sand in concrete casting. The water absorption test reveals that concrete cast with coastal sand exhibits the lowest absorption rate compared to control and laterite soil samples.

***Keywords**: Concrete; Strength; Construction; Laterite; Coastal; Alternative*

Introduction

Concrete is extensively used in construction worldwide, totaling two billion tons annually. Its composition typically includes cement, fine aggregates, coarse aggregates and water. However, the extraction of sand disrupts the environment's balance, prompting the search for alternative materials to reduce environmental impact. River sand mining exacerbates riverbed erosion, compromising the stability of nearby structures like bridges [1]. The composition of concrete primarily comprises fine and coarse aggregates, which typically constitute 60–75% of its volume. The properties and types of aggregates significantly influence the performance and quality of concrete [2].

The preservation of river soil is essential for environmental sustainability, biodiversity conservation and human well-being. River soil acts as a natural filter, trapping pollutants and sediment. Without preservation, water quality can degrade, disturbing aquatic ecosystems and potentially harming human health, as water is the main thing consumed by human beings. The usage of river soil unlimitedly will increase flooding due to lacking river soil as excess water absorption [3].

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A proposed resolution to this matter is to replace a portion of the fine aggregate with laterite and coastal sand. This is undertaken to assess the viability of using a blend of coastal sand and laterite alongside cement, coarse aggregate and water in formulating a concrete mixture. Additionally, it seeks to establish the optimal replacement ratio of fine aggregate with laterite and coastal sand to attain maximum concrete strength.

In this investigation, laterite was obtained from a construction site at Bukit Chabang, while coastal sand was collected from a shoreline in Kuala Perlis, Perlis, Malaysia. Each mix utilized Portland cement of the same type. Additionally, river sand with a particle size below 4.75mm served as the fine aggregate and coarse aggregate made up of granite stone ranged from 20mm to 4.75mm in size. The study's findings revealed the proportions of laterite and coastal sand utilized to optimize the effectiveness of concrete, based on previous research. Specifically, replacement levels for fine aggregate included 0%, 15%, 25% and 50% for laterite and 0%, 20%, 30% and 50% for coastal sand.

The research evaluated the compressive strength of the concrete at 7, 28 and 60 days of curing to assess the influence of prolonged curing periods on concrete mixes incorporating coastal sand and laterite soil. Additionally, various tests were conducted throughout the research project, such as compression strength, workability, rebound hammer test, density of concrete samples and water absorption test, to investigate the bonding behavior of the concrete when coastal sand and laterite soil were substituted.

Methodology

In this laboratory study, three different sets of samples were constructed: control, laterite and coastal samples. The control sample contained ordinary Portland cement, while the laterite sample included 15%, 25% and 50% proportions of laterite soil. In contrast, the coastal sample consisted of 20%, 30% and 50% proportions of coastal sand. Emphasis was placed on replacing the fine aggregate to determine the optimal percentage for achieving concrete grade 25. All concrete samples underwent curing periods of 7, 28 and 60 days to examine the long-term strength development of each sample.

The laterite soil is taken from Bukit Chabang, Perlis. The laterite soil has been air-dried and kept dry to avoid combining with other substances. Next steps: laterite soil that was retained on a 0.075mm sieve and passed through 4.75mm was selected to be used in this experimental study. In the meantime, coastal sand is taken from Kuala Perlis, Malaysia. Before sieving, the coastal sand would be dried and stored in a dry place. Fine aggregate would be partially replaced with coastal sand after being sieved to 4.75mm and retained at 0.075mm. Figure 1 indicates the flowchart of the research method used in this experimental study.

Results and discussion

Density Test

Figure 2 shows the comparison of density for all samples obtained from this experimental study. The highest density was observed in the sample containing 30% coastal sand, while the lowest density was recorded in the sample containing 50% laterite soil. Specifically, the sample with 30% coastal sand exhibited a density 1.70% higher than that of the control sample, whereas the sample with 50% laterite soil showed a density 6.43% lower than that of the control sample. The primary reason for the higher density of the coastal sand sample, compared to both the control and laterite samples, is the effective distribution of its particles throughout the concrete mixture, resulting in fewer voids in the hardened concrete. This finding reflects the finding obtained from a previous study [4].

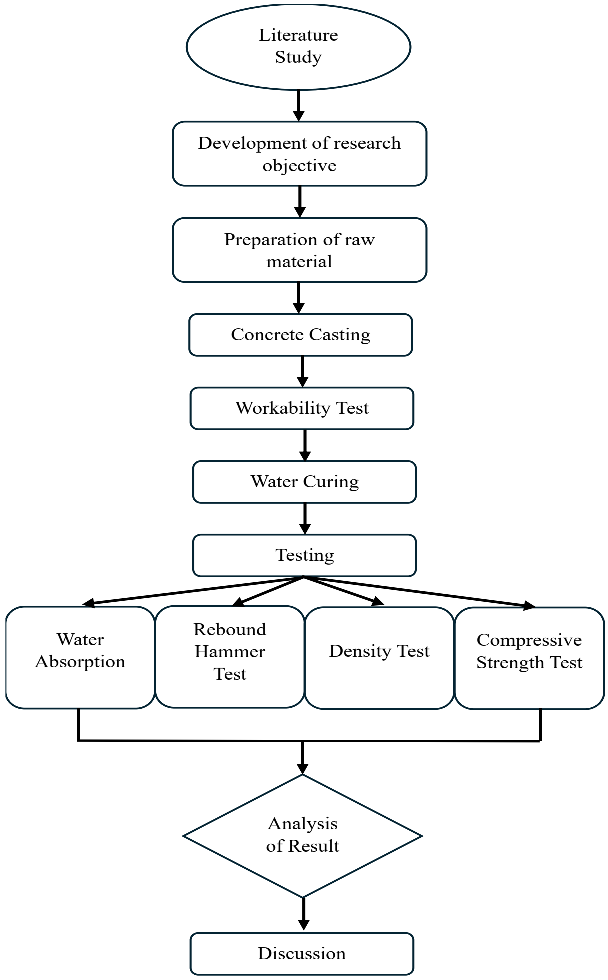

Fig. 1. Research Flowchart used in this experimental research study

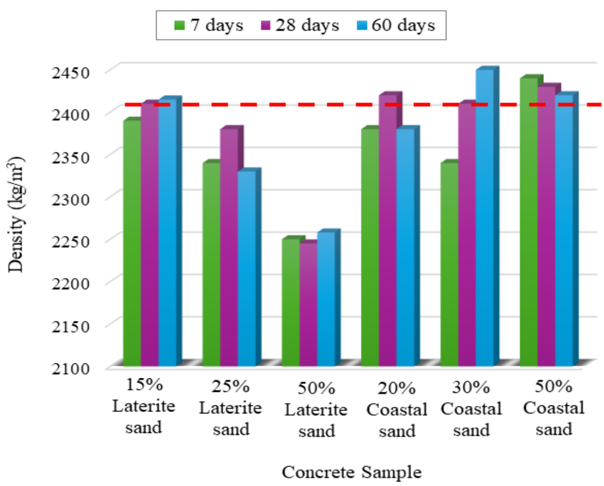

Fig. 2. Density test result for all concrete samples

The highest water absorption rate is 50% laterite samples, as shown in figure 3. Meanwhile, the lowest water absorption was observed in the concrete sample made with 50% coastal sand. Beyond a 50% inclusion of laterite content, additional fine particles are required. Consequently, the continued hydration of cement with laterite content may experience delays, resulting in heightened porosity and improved connectivity within the capillary pore network [5]. These findings suggest that the density of the 50% laterite samples contains sufficient filler material, thereby reducing porosity in the hardened concrete obtained at a 60-day curing period. Meanwhile, the coastal sand sample indicates the decrease of density as the concrete age reaches 60 days of curing period. This was attributed to a more comprehensive hydration of cement, resulting in increased formation of calcium silicate hydrate (CSH) to fill the pores within the concrete [6].

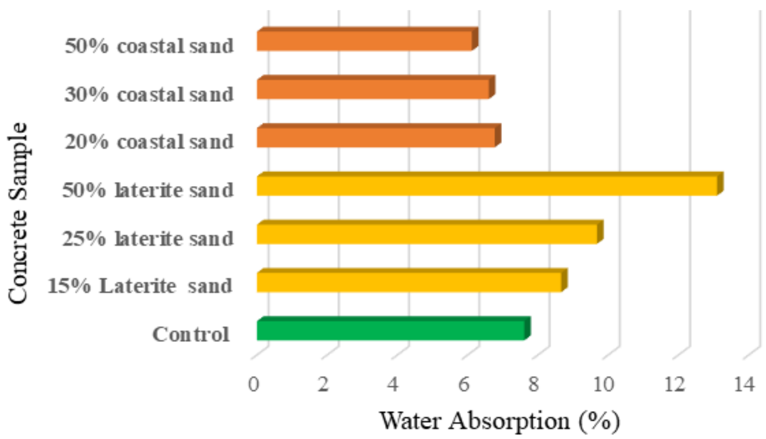

Fig. 3. Comparison of water absorption for all samples

The results from the samples indicated a gradual rise in the moisture content and porosity of the concrete with an increasing percentage of laterite replacement. This led to a slow but steady upward trend in the slow-state graph. Furthermore, it was observed that the laterite particles may not have fully occupied the pores of the concrete. However, as the replacement proportion increased, there was a slight reduction in coastal sand replacement. Elevating the coastal sand replacement in concrete could help minimize water absorption, thereby enhancing the strength and durability of the concrete.

Rebound Hammer

Figure 4 indicates the comparison of rebound hammer results for all samples. The plotted graph shows the highest rebound hammer reading obtained at 60 days of curing periods for all samples. At the 60-day curing period, the rebound hammer reading may be higher than the 28-day curing period due to the continued hydration and strengthening of the concrete over time. As concrete cures, the hydration process progresses, leading to further development of its internal structure and strength. The highest rebound hammer reading for laterite soil is recorded at 15%. Meanwhile, the highest average rebound hammer reading for a coastal sand sample is obtained at 50%. In contrast, the percentage difference between the maximum average rebound hammer reading between laterite and coastal sand is 16.4%.

The rebound hammer readings seem to be impacted by the higher percentage replacement of laterite. As depicted in the graph, an increase in replacement percentage leads to a decrease in rebound hammer readings for concrete cast using laterite sand. However, for coastal sand samples, an increase in replacement results in higher rebound hammer readings. Notably, the rebound hammer reading for the 50% coastal sand sample shows minimal deviation according to the plotted graph. This is because the lack of significant disparity in rebound hammer readings between the 28-day and 60-day curing periods for concrete with coastal sand suggests that the material may have achieved a substantial portion of its strength early in the curing process, with additional curing time beyond 28 days resulting in marginal increases in strength.

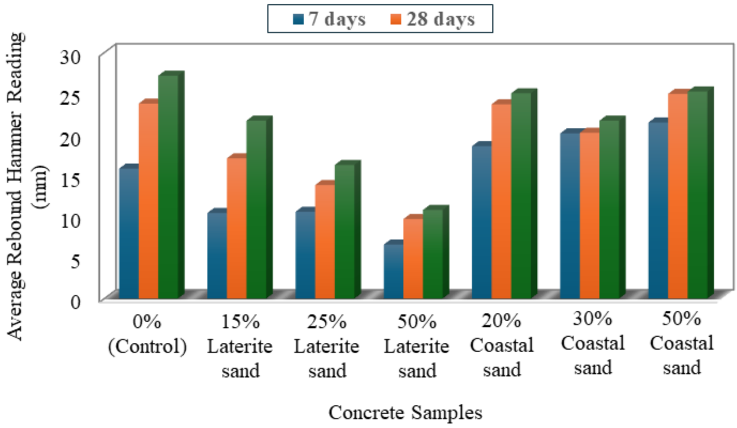

Fig. 4. Comparison of Average Rebound Hammer reading for all samples

However, concrete with an average rebound number valued at 20 to 30 is classified as fair quality and that concrete with a value of 20 or less was of poor quality [7]. The finding indicates that concrete cast using coastal sand performs well as compared with laterite soil. This was due to the increased porosity and air space of laterite particles compared to coastal sand. A higher porosity and air content often lead to a decreased compressive strength [8]. Moreover, there appears to be a 7% variance between the control samples in the average rebound hammer test results obtained from 50% coastal sand. Hence, it is recommended to increase the percentage of coastal sand to meet the requirements of the control sample.

Compression Strength

The highest compression strength was observed in the sample containing 50% coastal sand after a 60-day curing period, representing a 20.2% increase compared to the control sample. The concrete cast with laterite soil exhibited a slower strength development, as illustrated in figure 5.

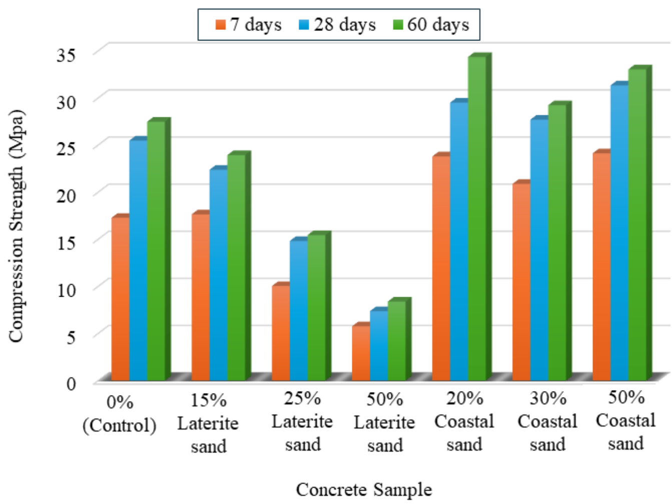

Fig. 5. Comparison of concrete strength for all samples

Among the laterite samples, the one containing 15% laterite soil approached the desired concrete strength most closely. The performance of concrete cast with coastal sand appeared to achieve a minimum strength of 25MPa at the 28-day curing period for all replacement percentages studied. The optimal replacement percentage for coastal sand was found to be 20%.

Conclusions

The density test results vary for each sample. The denser the concrete, the more it will contribute to the high concrete strength because it provides less porosity [9]. Water absorption reduced as the replacement percentage for laterite soil increased. Meanwhile, for coastal sand samples, as the replacement percentage increased, water absorption decreased. Several factors contribute to the decrease in water absorption for concrete samples cast using coastal sand, such as particle shape, gradation and porosity. The shape of particles and gradation of coastal sand can enhance the bonding between its particles, which will then lead to a reduction of permeability in concrete mix.

Rebound hammer result: The strength or number of rebounds in concrete varies according to the type of material applied. It showed that due to a different rebound number value, coastal sand replacement had greater strength than laterite. Higher compressive strength generally corresponds to higher rebound hammer values. Rebound hammer reading is also affected by physical appearance, moisture content, temperature and concrete age. As age increases, the rebound hammer values will increase. However, in contrast with moisture content and temperature, as these two factors increase, the rebound hammer values will decrease.

As the replacement percentage of both laterite and coastal sand increases, there appears to be a decline in the compressive strength of concrete. The optimal replacement percentages are found to be 15% for laterite and 50% for coastal sand. However, the compressive strength test conducted for replacing coastal sand yielded superior results compared to the control sample. This improvement can be attributed to the particle shape and gradation of coastal sand, which contributes to enhanced concrete strength development [17].

Overall, the combination of particle shape, gradation, moisture content, porosity and chemical composition makes coastal sand a preferable aggregate choice for achieving higher compressive strength in concrete compared to laterite soil. The chemical composition of laterite soil may contain minerals or compounds that can adversely affect the hydration process of cement and compromise the strength development of concrete. Coastal sand, being predominantly silica-based, does not introduce such deleterious effects and allows for optimal cement hydration, leading to higher compressive strength.

The finding obtained from this experimental study initiates the alternative way to mitigate the sole reliance on the river sand in the concrete industry. Coastal sand seems to be an alternative approach to be used in concrete production for future construction industries. In achieving natural resource conservation, the usage of coastal sand should be controlled.

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