PRELIMINARY TESTING OF COARSE AGGREGATE, FINE AGGREGATE, AND PALM KERNEL SHELL WASTE CHARACTERISTICS IN SUSTAINABLE CONSTRUCTION

Firmanilah Kamil[1], Nely Kurnila[2]
[1,2] Road and Bridge Engineering Technology, Politeknik Negeri Ketapang, Ketapang, Indonesia
firmanilahkamil@politap.ac.id

Abstract - This study aims to examine the characteristics of coarse aggregate, fine aggregate, and palm kernel shell waste as sustainable construction materials. The grain size distribution, specific gravity, moisture content, and content weight of the aggregates were analyzed to understand their effect on concrete performance. Results showed significant differences between coarse aggregate, fine aggregate, and palm kernel shell. The grain size distribution of palm kernel shells differs from natural aggregates, but its potential use is still relevant. The different specific gravity of the aggregate types has implications for concrete mix design. The use of palm kernel shells as aggregate has the potential to reduce structural load and environmental impact due to the lower specific gravity. Aggregate moisture content also affects the properties and performance of concrete mixes. The use of palm kernel shells as aggregate has the potential to affect the water characteristics of the mix and have a positive impact on the environment. Aggregate content weight informs aggregate density and porosity. The use of palm kernel shells has the potential to affect concrete density and provide thermal insulation. This study provides insight into developing sustainable construction materials through preliminary testing of aggregates.

Keywords—Aggregate; Palm Kernel Shell; moisture content; weight of contents,

I. Introduction

In construction, coarse and fine aggregates play a central role in shaping the mechanical and physical properties of concrete and other construction materials [1]. However, challenges related to the use of diminishing natural resources and the need for sustainable practices have encouraged the search for alternative construction materials [2]. In this context, palm kernel shell waste derived from the oil palm plantation industry has emerged as a potential candidate [3].

The utilization of waste in construction has the potential to reduce environmental impacts and dependence on natural resources [4]. Industrial waste, such as palm kernel shells, can be converted into construction materials that perform well in preliminary tests [5]. The use of these wastes in construction not only helps reduce the accumulation of industrial wastes but can also reduce the exploitation of increasingly scarce natural resources.

However, information on the characteristics and performance of palm kernel shells as construction materials is limited. Comprehensive preliminary testing of the physical, mechanical, and reactivity properties of palm kernel shells in various construction mixes is an important step in identifying the potential as well as the limitations of their use in sustainable construction practices [6].

In addition to industrial waste, construction waste itself also has the potential to be reused. Recycling of used concrete, for example, has become an increasingly popular trend in an effort to reduce construction waste and minimize environmental impact [7]. Reusing materials such as recycled concrete aggregates can reduce the need for new natural aggregates as well as reduce waste accumulated from previous construction projects [8].

Considering the limitations of natural resources, the need for sustainable practices in the construction industry, and the potential of utilizing waste as an alternative construction material [9], research on preliminary testing of coarse aggregates, fine aggregates, industrial waste such as palm kernel shells, as well as the reutilization of construction waste has significant relevance in the development of sustainable construction materials [10].

II. LITERATURE REVIEW

Research by Smith et al identified the importance of aggregate pre-testing in supporting sustainable construction [11]. They highlighted the relationship between aggregate quality, construction material performance, and environmental impact. The results

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of this study provide a basis for the need to analyze the performance of aggregate pre-testing in the context of sustainable development [12].

In his article, Johnson compared traditional aggregate testing methods with modern testing techniques such as 3D scanning and image analysis [13]. The research revealed that modern techniques are able to provide more detailed information about grain size distribution and physical properties of aggregates, which can lead to more accurate selection of construction materials.

The study by Garcia et al. explored the relationship between the physical properties of aggregates and the strength of the resulting concrete [14]. The study showed that grain size distribution and water absorption of aggregates have a significant influence on concrete performance. Therefore, analyzing the initial testing performance of aggregates is essential to ensure optimal concrete strength and durability.

The article by Lee and Chen discusses the validity of retesting the same aggregate using the same method [15]. This research identifies the extent to which the results of the initial test of the aggregate are reproducible, and provides insight into the reliability of the test.

Research by Wang et al. proposes an approach to integrate aggregate pretest results in structural design [10]. They present a method that allows structural engineers to select aggregates based on their physical characteristics, which in turn can improve the overall quality and performance of construction projects.

The analysis by Rahman et al. assessed the extent to which the aggregate pre-test results conformed to the applicable standards and regulations [16]. This research highlighted the importance of aggregate conformance to industry requirements, and underscored the need for accurate initial performance testing to ensure the quality of construction materials [17].

The study by Rahman et al explored the potential utilization of palm kernel shell waste in the construction industry, particularly in road construction [1]. The study involved the physical and mechanical characterization of palm kernel shells and its application in asphalt mixtures. The results showed that palm kernel shell waste has potential as a partial replacement for coarse aggregate in asphalt mixtures, contributing positively to the performance of road structures [18].

Further research by Ofori focused on the characteristics of concrete containing palm kernel shells as a replacement coarse aggregate [3]. Tests included compressive strength, tensile strength, and water absorption. The results show that the use of palm kernel shells can affect the mechanical properties of concrete, and this study provides insight into the potential utilization of industrial waste in concrete [19].

III. RESEARCH METHODS

The research was conducted at the Soil Laboratory of Road and Bridge Construction Engineering Technology of Ketapang State Polytechnic. The research method used was observation. The data in this study are in the form of material test results. Tests carried out include measuring grain distribution, moisture content, content weight, specific gravity, density, and water absorption.

This research aims to conduct preliminary testing of the characteristics of coarse aggregate, fine aggregate, and palm kernel shell waste as construction materials in the context of sustainable construction. The following methodology was followed in this research:

A. Material Collection

1) Coarse Aggregate: Samples of coarse aggregate from natural sources were taken for comparison purposes.

2) Fine Aggregate: Samples of fine aggregates from natural sources were taken for comparison purposes.

3) Palm Kernel Shells: Palm kernel shell samples were obtained from the oil palm plantation industry.

B. Sample Processing

1) Coarse Aggregate: The coarse aggregate samples were washed and screened to remove contamination and fine particles.
2) Fine Aggregate: The fine aggregate samples are sieved according to the desired fraction size.
3) Palm Kernel Shells: The palm kernel shells were dried, cleaned of contaminants, and broken into appropriate sizes.

C. Physical Characterization

Aggregate testing was conducted using 3 samples of each material, except for the grain size test.

1) Grain Size: The grain size of the aggregates was determined using sieve analysis as per ASTM standards.

2) Specific gravity: The specific gravity of the aggregates was measured using the water filling method.

3) Porosity: The porosity of the aggregate was calculated based on the difference in weight before and after immersion in water.

4) Weight Content: The content weight of the aggregates in the solid and loose state was measured using a balance sheet.

The test data were analyzed to compare the physical characteristics of coarse aggregate, fine aggregate, and palm kernel shell.

IV. RESEARCH RESULTS AND DISCUSSION

A. Aggregate Grain Size

Grain size tests were conducted on sand, crushed stone, and palm kernel shell to evaluate the grain size distribution of each aggregate type. The data from these grain size tests were then analyzed to provide further insight into the physical characteristics of the aggregates. The test results can be seen in Table 1.

From the results of the aggregate grain size test, it can be seen that the grain size distribution of each type of aggregate is significantly different. The coarse aggregate from nature has a fairly even distribution. However, the fine aggregate and palm kernel shells show a slightly more skewed distribution.

TABLE 1. AGGREGATE GRAIN SIZE TESTING RESULTS

Sieve Size (mm)	Coarse Aggregate (%)	Fine Aggregate (%)	Palm Kernel Shells (%)
50	0	0	0
37,5	0	0	0
30	0	0	0
25	3,584	0	0
19	28,292	0	0
14,25	57,293	0	0,4
13	10,702	0	39,2
9,5	0,04	0	17,8
4,75	0,0415	0	28,35
2,36	0,0475	0,3305	14,25
1,18	0	7,2505	0
1	0	8,239	0
0,60	0	40,952	0
0,30	0	30,4295	0
0,20	0	8,899	0
0,15	0	1,667	0
0,075	0	1,5995	0
pan	0	0,633	0

1) Coarse Aggregates: The grain size distribution of coarse aggregates shows that the majority of grain sizes are in the range of 13 mm to 19 mm. This is consistent with the characteristics of coarse aggregates in general.

2) Fine Aggregate: In the case of fine aggregates, the majority of grain sizes are in the range of 0.30 mm to 0.60 mm, which indicates that these aggregates have a finer texture than coarse aggregates.

3) Palm Kernel Shells: The grain size distribution of palm kernel shells shows that the majority of grain sizes are in the range of 2.36 mm to 13 mm, but with a higher proportion at 4.75 mm. This result is in accordance with the characteristics of palm kernel shells, which can be broken down into more varied sizes.

Grain size distribution testing provides useful information in designing an optimal concrete mix. Differences in grain size distribution between coarse aggregate, fine aggregate, and palm kernel shell can affect the filling properties and density of concrete. A deeper understanding of these characteristics can help in developing more efficient and sustainable concrete mixes.

B. Results of Aggregate Specific Weight Testing

Similar to the grain test, the specific gravity test also aims to provide further understanding of the physical characteristics of the aggregate. The test data can be seen in Table 2.

From the results of the aggregate specific gravity test, it can be seen that each type of aggregate has a different specific gravity. The specific gravity of aggregates is an important indicator in the design of concrete mixes because it affects the weight and density of the concrete produced.

TABLE 2. AGGREGATE SPECIFIC WEIGHT TESTING DATA

Sample	Specific Weight (kg/m^3)
Coarse aggregate 1	1452
Coarse aggregate 2	1461
Coarse aggregate 3	1435
Fine aggregate 1	1362
Fine aggregate 2	1431
Fine aggregate 3	1389
Palm Kernel Shells 1	1190
Palm Kernel Shells 2	1214
Palm Kernel Shells 3	1187

1) Coarse Aggregate: The specific gravity of coarse aggregate falls within the range of 1435 kg/m^3 to 1461 kg/m^3. Coarse aggregate has a lower specific gravity than fine aggregate and palm kernel shell.

2) Fine Aggregate: The specific gravity of fine aggregates is within the range of 1362 kg/m^3 to 1389 kg/m^3. The specific gravity of fine aggregates tends to be higher than that of coarse aggregates, which can have an impact on the density and workability of concrete.

3) Palm Shells: The specific gravity of palm shells is in the range of 1187 kg/m^3 to 1214 kg/m^3. The much lower specific gravity of palm kernel shells indicates a potential reduction in concrete weight when used as an aggregate material.

Aggregate specific gravity test results provide important information for the design of sustainable structures. The potential use of palm kernel shells as aggregate materials in construction shows that these materials have a lower specific gravity. This can provide benefits in reducing structural loads and environmental impacts.

C. Test Results for Moisture Content and Porosity

Moisture content tests were conducted on three coarse aggregate samples, three fine aggregate samples, and three palm kernel shell samples to evaluate the ability of the aggregates to hold water. The data from this test was analyzed to provide further understanding of the porosity properties of the aggregates. The test results can be seen in Table 3.

TABLE 3. MOISTURE CONTENT TEST RESULTS

Sample	Moisture Content (%)
Coarse aggregate 1	0,61
Coarse aggregate 2	1,26
Coarse aggregate 3	1,56
Fine aggregate 1	8,02
Fine aggregate 2	8,70
Fine aggregate 3	7,43
Palm Kernel Shells 1	17,76
Palm Kernel Shells 2	16,88
Palm Kernel Shells 3	17,57

From the results of the aggregate moisture content test, it can be seen that each type of aggregate has a different ability to hold water.

1) Coarse Aggregate: The coarse aggregate shows a low moisture content (0.61% to 1.56%). This indicates that the coarse aggregate has a good ability to hold water, which can contribute to the performance of the concrete mix.

2) Fine Aggregates: The moisture content of fine aggregate is slightly higher (7.43% to 8.70%) than that of coarse aggregate. Despite the higher moisture content, the fine aggregate still has a fairly good ability to hold water.

3) Palm Kernel Shells: The higher moisture content of palm kernel shells (16.88% to 17.76%) indicates that these shells have greater water absorption. This is consistent with the porosity and texture properties of palm kernel shells.

Testing the moisture content of aggregates provides important information in designing an optimal concrete mix. The ability of aggregates to hold water can affect the consistency of the concrete mix and the final properties of the resulting concrete. The use of palm kernel shells as an aggregate material in sustainable construction has the potential to influence the water characteristics of the mix and the final properties of the concrete.

D. Aggregate Content Weight Testing Results

Content-weight tests were conducted on three coarse aggregate samples, three fine aggregate samples, and three palm kernel shell samples to evaluate the solid content and loose content weight of each type of aggregate. The data from these tests were analyzed to provide further understanding of the density and pore space of the aggregates. The test data can be seen in Table 4.

TABLE 4. WEIGHT CONTENT TEST RESULTS

Sample	Weight of Solid Contents (kg/m^3)	Loose Fill Weight (kg/m^3)
Coarse aggregate 1	1330	1278
Coarse aggregate 2	1321	1290
Coarse aggregate 3	1345	1265
Fine aggregate 1	1566	1490
Fine aggregate 2	1578	1458
Fine aggregate 3	1550	1480
Palm Kernel Shells 1	456	398
Palm Kernel Shells 2	431	400
Palm Kernel Shells 3	440	389

From the results of the aggregate content weight test, we can observe the differences in characteristics between coarse aggregate, fine aggregate, and palm kernel shell.

1) Coarse Aggregate: The solid content weight of coarse aggregate ranges from 1321 to 1345, while the loose content weight ranges from 1265 to 1290. The difference between the solid and loose weight contents indicates the amount of pore space or vacuum in the aggregate [20].

2) Fine Aggregates: The solid content weight of fine aggregates ranges from 1550 to 1578, while the loose content weight ranges from 1458 to 1490. The higher loose weight content of fine aggregates indicates the presence of larger pore spaces than coarse aggregates [21].

3) Palm Kernel Shells: The solid contents weight of palm kernel shells ranged from 431 to 456, while the loose contents weight ranged from 389 to 400. The significant difference between the solid and loose contents weight of palm kernel shells indicates the open nature of the shaft and structure.

The results of the aggregate content weight test provide an understanding of the density and porosity of each type of aggregate. The use of aggregates with a higher solid content weight can result in concrete that is denser and has less pore space [22]. However, the use of aggregates with higher friable contents, such as palm kernel shells, can provide benefits in reducing concrete weight and providing thermal insulation [23].

The results of the aggregate content weight test provide an understanding of the density and porosity of each type of aggregate. The use of aggregates with a higher solid content weight can result in concrete that is denser and has less pore space. However, the use of aggregates with higher friable contents, such as palm kernel shells, can provide benefits in reducing the weight of the concrete and providing thermal insulation [24].

Research results on the grain size distribution, specific gravity, moisture content, and content weight of aggregates bring us to a deeper understanding of the significant differences between coarse aggregates, fine aggregates, and palm kernel shells in a construction context. Other recent research has also measured these parameters for other aggregates, such as river sand and natural gravel, and found interesting variations in the properties of these aggregates.

In the context of grain size distribution, recent research has shown that coarse aggregates have a more varied grain distribution compared to fine aggregates, which tend to have a more uniform grain distribution. Palm kernel shell, on the other hand, has a very different grain distribution from both types of natural aggregates. These variations can have a significant impact on the mechanical properties of the concrete mix and should therefore be carefully considered in the design of the optimal concrete mix.

In addition to grain size distribution, specific gravity is also an important factor in determining the properties of aggregates. Recent research has shown that the specific gravity of coarse aggregates is generally higher than that of fine aggregates, while palm kernel shells have a much lower specific gravity. This variation in specific gravity can have important implications in concrete mix design. For example, aggregates with low specific gravity, such as palm kernel shells, can reduce the structural load on construction and contribute to sustainable construction.

In addition, the potential utilization of palm kernel shells as aggregate materials in construction remains relevant, even though their grain size distribution differs from natural aggregates. Other studies have emphasized the environmental benefits of using palm kernel shells as aggregate materials, as their lower specific gravity can reduce the environmental impact of aggregate transportation. In addition, the use of palm kernel shells can also help reduce waste from the palm oil industry.

In the context of this study, recent research results have expanded our understanding of the importance of grain size distribution and specific gravity of aggregates in the design of optimal concrete mixes. The utilization of palm kernel shells as aggregate materials in sustainable construction is emerging as an attractive option that can reduce structural loads and environmental impacts, despite the significant differences in aggregate properties compared to natural aggregates. With further research and technological development, the potential utilization of palm kernel shells in construction could become a more sustainable and environmentally friendly alternative.

Besides the variables of grain size distribution and specific gravity, the difference in moisture content between different types of aggregates is also a crucial factor that needs to be considered in the design of concrete mixes. Recent research has shown that aggregate moisture content has a significant influence on the properties and performance of concrete mixes. Aggregates that have a high moisture content, as is often the case with palm kernel shells, can cause the concrete mix to become more fluid, which in turn can affect the strength and durability of the mix.

Other experimental studies have observed that increasing the moisture content in concrete mixtures can reduce the compressive strength of concrete, but can otherwise improve the workability of the mixture and the ability to fill molds well. Therefore, the use of palm kernel shells as aggregate material in sustainable construction should consider adjusting the concrete mix design to compensate for this difference in moisture content.

However, the potential utilization of palm kernel shells in sustainable construction is not only related to the properties of concrete mixes. The use of palm kernel shells as aggregate materials can also have a positive impact on the environment. A number of studies have highlighted the environmental benefits of using palm kernel shells, including waste reduction in the palm oil industry and reduced environmental impact in aggregate transportation.

The use of palm kernel shells as an aggregate material in sustainable construction not only changes the water characteristics of concrete mixes, but also opens up opportunities to reduce the environmental footprint of the construction sector. With the right approach in mix design and careful monitoring, the potential utilization of palm kernel shells as aggregate material can result in efficient and sustainable concrete mixes and support environmental conservation efforts.

The study of the solid and friable contents of different types of aggregates is essential in understanding the physical characteristics of aggregates. The results of this study can provide an in-depth insight into the density and porosity of aggregates, which in turn have a significant effect on the properties of concrete mixes.

Recent research has revealed that palm kernel shell aggregate, as an example of an alternative aggregate, has a significantly different weight content compared to traditional aggregates. Palm kernel shell, with its natural porosity, generally has a lower solid weight content than conventional coarse aggregates. However, its loose weight may be higher. The results of this study bring out the potential influence of palm kernel shell aggregate on concrete density.

In addition, the utilization of palm kernel shells in construction can also have a positive impact in certain construction situations. Several studies have highlighted the thermal insulation benefits presented by palm kernel shells in concrete mixes. With its unique porosity characteristics, palm kernel shell can act as an effective thermal insulator. This means that the use of palm kernel shells in construction may provide additional advantages in regulating the temperature in buildings, which is particularly important in hot or cold climates.

In addition, other studies have highlighted the environmental benefits of using palm kernel shells in construction. Lighter aggregate materials, such as palm kernel shells, can reduce energy consumption in transportation and material use. This means that the use of palm kernel shells not only affects the density of concrete and its thermal properties, but also makes a positive contribution to the sustainability of construction.

The incorporation of these elements in concrete mix design can open up opportunities to optimize the physical and thermal characteristics of concrete in various construction situations. With a deeper understanding of the solid weight, loose weight, and environmental and thermal benefits of alternative aggregates such as palm kernel shell, the construction industry can take further steps in achieving sustainability and efficiency in its projects.

V. CONCLUSIONS AND SUGGESTIONS

The test results of grain size distribution, specific gravity, moisture content, and content weight of aggregates showed significant differences between coarse aggregate, fine aggregate, and palm kernel shell. Different grain size distributions need to be considered in the design of an optimal concrete mix to achieve the desired mechanical and physical properties. The potential utilization of palm kernel shells as aggregate materials in construction remains relevant, even though their size distribution differs from natural aggregates. The different specific gravity of each type of aggregate has important implications in concrete mix design and overall construction. The utilization of palm kernel shells as aggregate materials in sustainable construction has the potential to reduce structural loads and environmental impacts due to their lower specific gravity.

In addition, differences in the moisture content of each type of aggregate can affect the properties and performance of concrete mixes. The use of palm kernel shells as aggregate materials in sustainable construction has the potential to affect the water characteristics of the mix and have a positive impact on the environment.

The solid and friable contents weight of each type of aggregate provides an understanding of the density and pore space of the aggregate. The utilization of palm kernel shell aggregate has the potential to affect the density of concrete and have a positive impact on weight and thermal insulation in certain construction situations.

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