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Study of The Addition of Palm Shall Ash on Increasing Compressive Strength of Paving Block

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Keywords

palm shell ash, paving block, compressive strength

Abstract

Increasing development, the demand for building materials such as paving blocks is also increasing. With the many variations offered, the material for making paving blocks is not just a mixture of cement and sand. Crushed stone or gravel or other additives can also be used. In this study, palm shell ash was chosen as an additional material in making paving blocks, in order to increase the compressive strength of the paving blocks. This study was conducted by making 48 test specimens, then testing the compressive strength after the test specimens were soaked according to the predetermined planned age. This study refers to the implementation method of SNI 03-0691-1996 concerning concrete bricks (paving blocks). To obtain the optimal composition, various palm shell ash was added. Compressive strength testing was carried out when the test specimens reached the planned age. The results of the compressive strength test that had been carried out, it was found that the optimal addition of palm shell ash occurred at an addition of 8% at a soaking age of 28 days. So by referring to the regulations, concrete bricks (paving blocks) are included in the class C/IIIa quality category.

INTRODUCTION

Global infrastructure development is currently experiencing very rapid growth, especially in developing countries. Along with this growth, the need for quality, efficient, and environmentally friendly building materials is also increasing. One of the materials widely used in the construction of lightweight infrastructure is paving blocks, which function as an alternative to ground cover, replacing conventional asphalt and concrete. Amidst this increasing need, a new challenge arises: how to provide building materials that are not only high quality but also cost-effective and environmentally friendly. One of the relevant global issues in this context is the management of palm oil industry waste, which is one of the main commodities in Southeast Asia, including Indonesia. Waste from the burning of palm shells, especially palm shell ash, is considered to have great potential as an additional material in construction, especially to increase the strength of cement-based products such as paving blocks.

The problems that arise in the construction sector today are not only limited to the limitations of natural raw materials such as sand and gravel, but also the increasing volume of industrial waste that has not been managed optimally. One of the main factors is the lack of innovation in the use of waste as a substitute or additional material in building materials. Palm shell ash waste, for example, is often simply dumped or simply piled up in palm oil processing plant areas, thus causing potential environmental pollution. In addition, the use of conventional building materials such as cement and natural aggregates in large quantities also has an impact

on the exploitation of natural resources and increased carbon emissions in the production process (Graille, 1985; Abdullah, 2010). This condition demands a solution based on technology and material engineering that can overcome two problems at once: reducing environmental pollution and increasing the efficiency of construction materials.

The impacts of the above problems are quite complex. The inability to manage waste such as palm shell ash contributes to the increasing volume of unused industrial waste, while also causing serious environmental problems, especially in palm oil producing areas such as North Sumatra. On the other hand, the construction industry faces challenges in meeting the demand for high-quality materials at competitive costs. Dependence on primary raw materials such as cement and sand also has an impact on rising construction prices and the gradual reduction of natural reserves. Therefore, innovation in creating alternative building materials from industrial waste is a strategic step to answer this challenge.

This study specifically raises two main variables, namely palm shell ash as the independent variable (X) and the compressive strength of paving blocks as the dependent variable (Y) . Palm shell ash is the result of burning solid waste from the palm oil processing process which generally contains high amounts of silica (SiO_2), which is around 67% (FMIPA USU, 2011). The silica content makes palm shell ash have pozzolanic properties, namely the ability to react with calcium hydroxide in cement and form compounds that strengthen concrete. Meanwhile, the compressive strength of paving blocks refers to the ability of concrete products to withstand compressive loads, which is an important parameter in assessing their quality and classification according to the SNI 03-0691-1996 standard. By integrating palm shell ash into the paving block mixture, this study aims to evaluate the extent to which this waste can significantly increase the strength of paving block products.

The uniqueness (novelty) of this study lies in the experimental approach carried out systematically by using variations in the composition of palm shell ash (2%, 4%, 6%, 8%, and 10%) to the cement and sand mixture. In addition, testing was carried out at four different immersion ages (7, 14, 21, and 28 days) to obtain a comprehensive picture of the development of compressive strength from each variation. Although several previous studies have examined the use of agricultural waste in concrete, very few have specifically tested the effect of variations in palm shell ash content on the compressive strength of paving blocks with tiered testing based on immersion age. Therefore, this study not only contributes to the technical literature on alternative materials, but also presents empirical data that can be directly utilized by the construction industry and local paving block business actors.

The urgency of this research is increasing along with the increasing national and global focus on the implementation of sustainable development principles, especially in the construction sector. Efforts to use waste as a construction material not only have a positive impact on the environment, but also contribute to creating a circular economy, where waste from one industry becomes a resource for another industry. Given the enormous potential of palm shell waste in Indonesia, its use as an additional material for paving blocks is not only innovative from a technical perspective, but also strategic from an environmental and economic perspective. Moreover, paving blocks are products that are widely used in small to large-scale construction, so the opportunities for applying the results of this research are very broad and applicable.

The main objective of this study was to determine the effect of adding palm shell ash on the compressive strength of paving blocks, and to identify the optimal composition that can provide the highest compressive strength results. This study used a laboratory experimental method by making 48 paving block test specimens, each of which was tested for strength at the age of 7, 14, 21, and 28 days. The process of making test specimens refers to the SNI method, and the test results are then classified according to the quality standards of concrete bricks. Through this study, it is expected to obtain valid data on the most effective palm shell ash

content in improving the quality of paving blocks, as well as providing practical recommendations to paving industry players.

The benefits of this research can be seen from several sides. First, environmentally, this research provides an alternative utilization of palm shell ash waste that has not been maximized so far. Second, from a technical perspective, this research can provide important input in the development of waste-based building materials that are not only cheap but also high-performance. Third, from an industrial perspective, the results of this research have the potential to be used by paving block business actors, especially in palm oil producing areas, as a basis for more competitive and sustainable product innovation. Fourth, academically, this research is a source of reference for further studies that focus on the utilization of organic waste as an alternative construction material.

RESEARCH METHODS

This research is a type of qualitative research with a descriptive approach, which aims to obtain an empirical and objective picture of the effect of adding palm shell ash on increasing the compressive strength of paving blocks. The descriptive approach is used to observe, record, analyze, and present phenomena that occur systematically. With this approach, researchers not only measure the strength of the material, but also interpret the relationship between independent and dependent variables contextually and in depth. The main focus in this approach is to develop a comprehensive understanding of how palm shell ash as an additional material can contribute to the quality of paving block products based on experimental testing.

This research was conducted in three different locations to support the completeness of the testing process. Testing of raw materials and sand was conducted at the Concrete Laboratory of the Medan State Polytechnic, while the process of printing paving block test objects was conducted at the Paving Block Factory CV. Sarah Idola Medan, and compressive strength testing was conducted at the Concrete Technology Laboratory of the Medan State Polytechnic. The selection of this location was based on the availability of adequate tools and facilities to support all stages of the research, from material processing, printing test objects, to laboratory tests. This research was conducted over a period of three months, starting from the beginning of the preparation of materials and equipment, the process of printing test objects, soaking, to testing compressive strength at each age of the test object.

The population in this study was all possible paving block mixtures that can be made from a combination of sand, cement, and palm shell ash, with various composition variations that have been mentioned. The samples used in this study consisted of 48 hexagonal paving block test objects , measuring 16 cm long, 9.5 cm wide, and 6 cm high. These test objects were divided into six categories based on their mixture composition: normal paving blocks (without additions), and five mixtures with variations in the addition of palm shell ash (2%, 4%, 6%, 8%, and 10%). Each category had 8 test objects which were then tested at four different times according to the immersion age. This number is considered sufficient to obtain representative and scientifically accountable data.

The instruments used in this study consisted of various tools and testing devices. The main instrument is a compressive strength tester, which is used to measure the resistance of paving blocks to direct pressure. In addition, a hexagonal paving block mold made of iron plate is also used to ensure the uniformity of the shape and size of each test object. In the process of mixing and weighing materials, digital scales, aggregate sieves, and manual mixers are used. In addition to physical instruments, observation sheets and test records are also used to document each process, from mixing materials, molding, soaking process, to when the compressive strength test is carried out. All instruments are designed and prepared to ensure the accuracy of the results and the validity of the data obtained during the study.

RESULTS AND DISCUSSION

Paving Block Compressive Strength Test Results 7 Days Old

From table 1 it can be seen that at the age of 7 days, a greater increase in paving blocks occurred with the addition of 8% palm shell ash and after the addition of 10% palm shell ash, there was a decrease in the compressive strength of paving blocks.

Table 1. Compressive Strength Test Results at 7 Days

No.	Test Object Name	Test Object Weight (Kg)	Compressive Load (Kg)	Test Field Area (cm2)	Compressive Strength (Kg/ cm^2)
1.	Normal PB	2293	18000	191.19	94.14
2.	PB + ACS 2%	2221	19250		100.68
3.	PB + ACS 4%	2258.5	21500		112.45
4.	PB + ACS 6%	2281.5	22750		118.99
5.	PB + ACS 8%	2239	24250		126.83
6.	PB + ACS 10%	2284	22500		117.68

The following is the calculation of the compressive strength test value of paving blocks:

Normal PB compressive strength = P/ A = 18000/191.19 = 94.14 kg/cm2.

Compressive strength PB + ACS 2%= P/ A = 19250/191.19 = 100.68 kg/cm2.

Compressive strength PB + ACS 4% = P/ A = 21500/191.19 = 112.45 kg/cm2

(For further details, please see table 1)

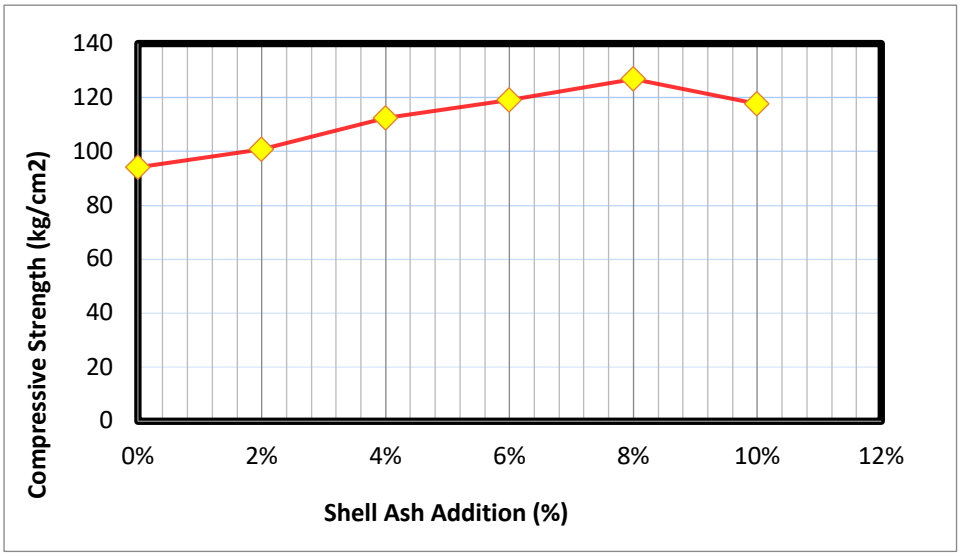

Figure 1. Relationship between the addition of palm kernel shell ash and compressive strength at 7 days of age

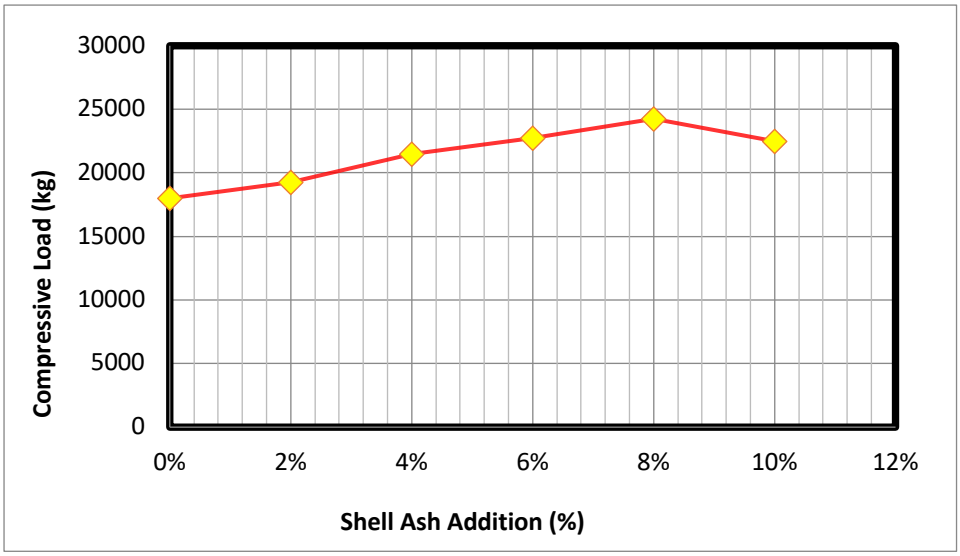

Figure 2. Relationship between the addition of palm kernel shell ash and the compressive load at 7 days of age

It is also explained in Figures 1 and 2, at the planned age of 7 days, paving blocks with variations in the addition of palm shell ash experienced an increase in compressive strength. The increase in compressive strength ranged between 6-15 kg/cm2.

A greater increase in compressive strength (maximum) occurred with the addition of 8% palm shell ash, however after the addition of a 10% mixture variation, there was a decrease in the compressive strength of the paving block.

So from the results obtained at the age of 7 days, it can be concluded that the optimal value of adding palm shell ash occurs at a variation of 8% with a compressive strength value of 126.83 kg/cm2. If referring to the SNI 03-0691-1996 regulation (specification of quality requirements for concrete bricks/paving blocks) then this value is included in the IIIb/D Quality category.

Paving Block Compressive Strength Test Results 14 Days Old

From table 2 it can be seen that at the age of 14 days, a greater increase in paving blocks occurred with the addition of 8% palm shell ash and after the addition of 10% palm shell ash, there was a decrease in the compressive strength of paving blocks.

Table 2. Compressive Strength Test Results at 14 Days

No.	Test Object Name	Test Object Weight (Kg)	Compressive Load (Kg)	Test Field Area (cm2)	Compressive Strength (Kg/ cm^2)
1.	Normal PB	2305	22750	191.19	118.99
2.	PB + ACS 2%	2303.5	22750		118.99
3.	PB + ACS 4%	2309	23750		124.22
4.	PB + ACS 6%	2258.5	25750		134.68
5.	PB + ACS 8%	2252	26750		139.91
6.	PB + ACS 10%	2258	25250		132.06

The following is the calculation of the compressive strength test value of paving blocks:
Normal PB compressive strength = P/ A = 22750/191.19 = 118.99 kg/cm2.
Compressive strength PB + ACS 2%= P/ A = 22750/191.19 = 118.99 kg/cm2.
Compressive strength PB + ACS 4% = P/ A = 23750/191.19 = 124.22 kg/cm2 (For further details, see table 2)

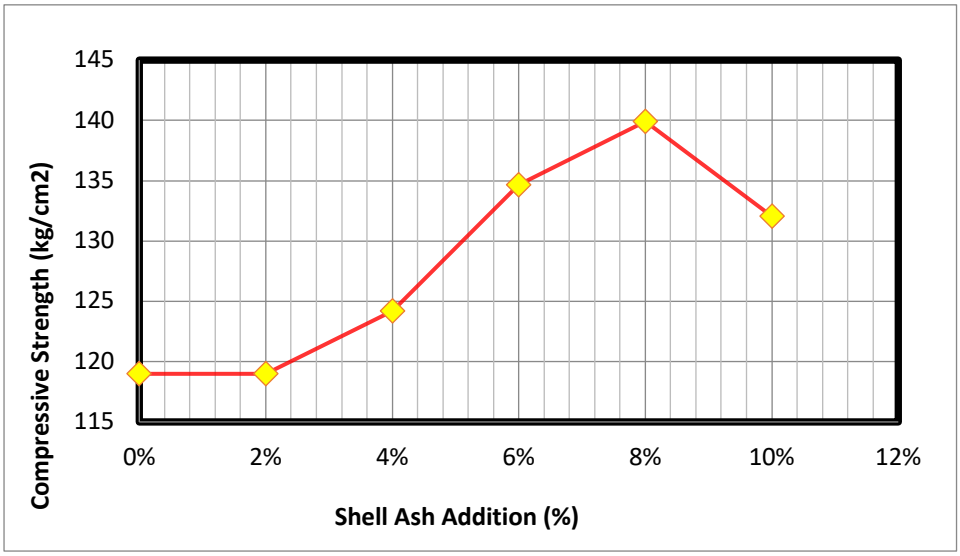

Figure 3. Relationship between the addition of palm shell ash and compressive strength at 14 days of age

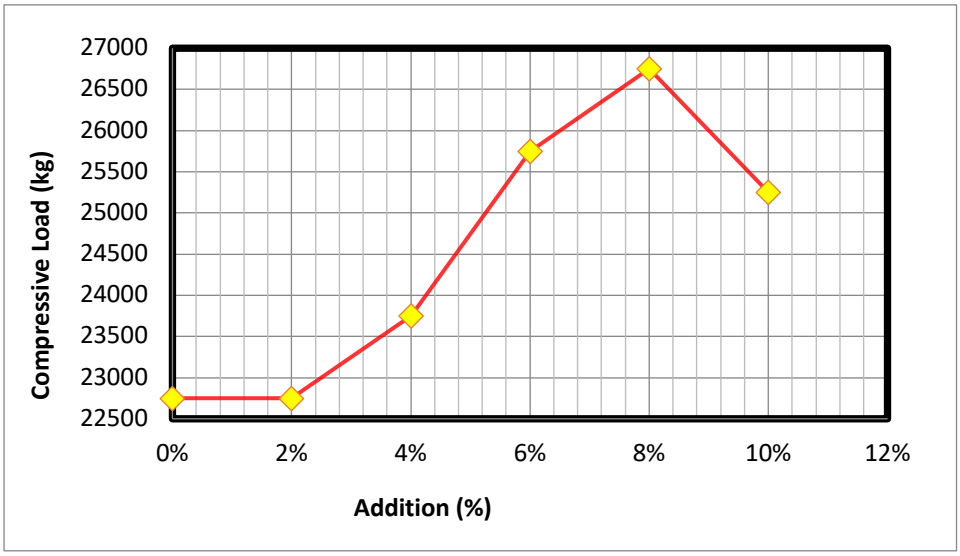

Figure 4. Relationship between the addition of palm kernel shell ash and the compressive load at 14 days of age

From Figures 3 and 4, at the planned age of 14 days, paving blocks with variations in the addition of palm shell ash experienced an increase in compressive strength. The increase in compressive strength ranged between 5-10 kg/cm2.

A greater increase in compressive strength (maximum) occurred with the addition of 8% palm shell ash, however after the addition of a 10% mixture variation, there was a decrease in the compressive strength of the paving block.

So from the results obtained at the age of 14 days, it can be concluded that the optimal value of adding palm shell ash occurs at a variation of 8% with a compressive strength value of 139.91 kg/cm2. If referring to the SNI 03-0691-1996 regulation (specification of quality requirements for concrete bricks/paving blocks) then this value is included in the IIIb/D Quality category.

Paving Block Compressive Strength Test Results 21 Days Old

From table 3 it can be seen that at the age of 21 days, a greater increase in paving blocks occurred with the addition of 8% palm shell ash and after the addition of 10% palm shell ash, there was a decrease in the compressive strength of paving blocks.

Table 3. Compressive Strength Test Results at 21 Days

No.	Test Object Name	Test Object Weight (Kg)	Compressive Load (Kg)	Test Field Area (cm2)	Compressive Strength (Kg/ cm^2)
1.	Normal PB	2328	26000	191.19	135.98
2.	PB + ACS 2%	2221.5	27250		145.52
3.	PB + ACS 4%	2280.5	28500		149.06
4.	PB + ACS 6%	2274	30250		158.21
5.	PB + ACS 8%	2303	31750		166.06
6.	PB + ACS 10%	2292	28250		147.75

The following is the calculation of the compressive strength test value of paving blocks:

Normal PB compressive strength = P/ A = 26000/191.19 = 135.98 kg/cm2.

Compressive strength PB + ACS 2%= P/ A = 27250/191.19 = 145.52 kg/cm2.

Compressive strength PB + ACS 4% = P/ A = 28500/191.19 = 149.06 kg/cm2 (For further information, see table 5)

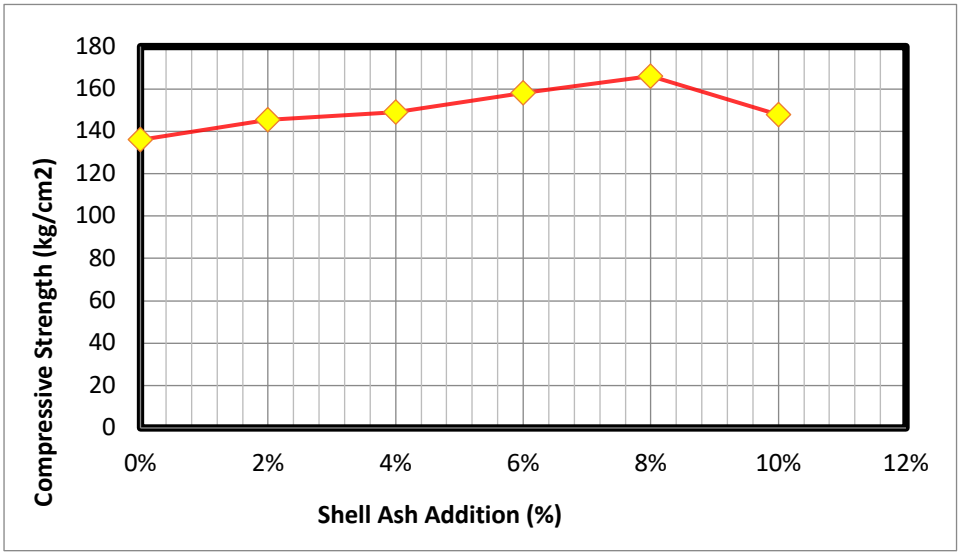

Figure 5. Relationship between the addition of palm kernel shell ash and compressive strength at 21 days of age

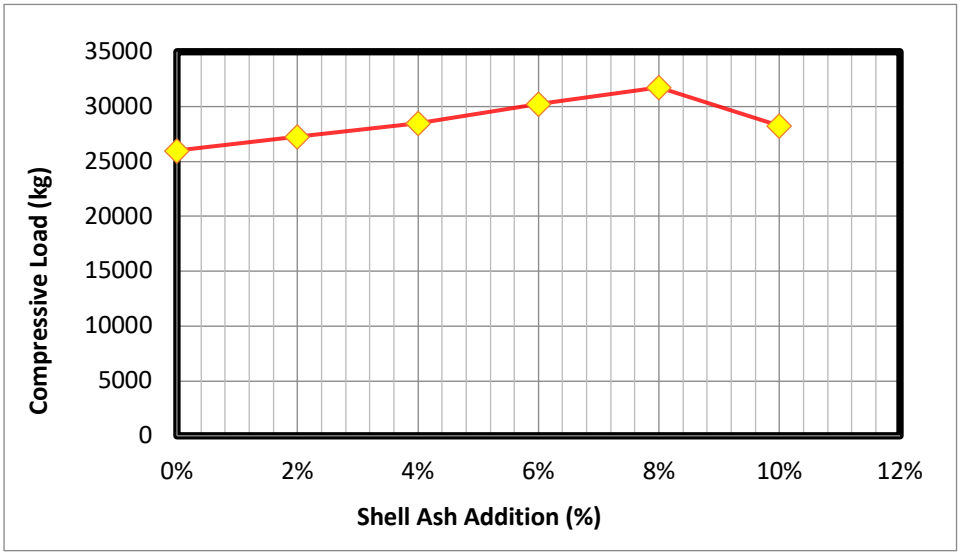

Figure 6. Relationship between the addition of palm kernel shell ash and the compressive load at 21 days of age

At the planned age of 21 days, paving blocks with variations in the addition of palm shell ash experienced an increase in compressive strength. The increase in compressive strength ranged between 6-15 kg/cm2 (can be seen in figures 5 and 6).

A greater increase in compressive strength (maximum) occurred with the addition of 8% palm shell ash, however after the addition of a 10% mixture variation, there was a decrease in the compressive strength of the paving block.

So from the results obtained at the age of 21 days, it can be concluded that the optimal value of adding palm shell ash occurs at a variation of 8% with a compressive strength value of 166.06 kg/cm2. If referring to the SNI 03-0691-1996 regulation (specification of quality requirements for concrete bricks/paving blocks) then this value is included in the IIIa/C Quality category.

Compressive Strength Test Results at 28 Days

From table 4.4 it can be seen that at the age of 28 days, a greater increase in paving blocks occurred with the addition of 8% palm shell ash and after the addition of 10% palm shell ash, there was a decrease in the compressive strength of paving blocks.

Table 4. Compressive Strength Test Results at 28 Days

No.	Test Object Name	Test Object Weight (Kg)	Compressive Load (Kg)	Test Field Area (cm2)	Compressive Strength (Kg/ ^{cm2})
1.	Normal PB	2314	29750	191.19	155.60
2.	PB + ACS 2%	2294.5	30000		156.90
3.	PB + ACS 4%	2318.5	32250		168.67
4.	PB + ACS 6%	2276.5	34250		179.13
5.	PB + ACS 8%	2295.5	37250		194.82
6.	PB + ACS 10%	03-Aug-15	30-Aug-15	2270.5	31000 162.13

The following is the calculation of the compressive strength test value of paving blocks:

Normal PB compressive strength = P/ A = 29750/191.19 = 155.60 kg/cm2.

Compressive strength PB + ACS 2%= P/ A = 30000/191.19 = 156.90 kg/cm2.
Compressive strength PB + ACS 4% = P/ A = 32250/191.19 = 168.67 kg/cm2
(For further information, see table 1)

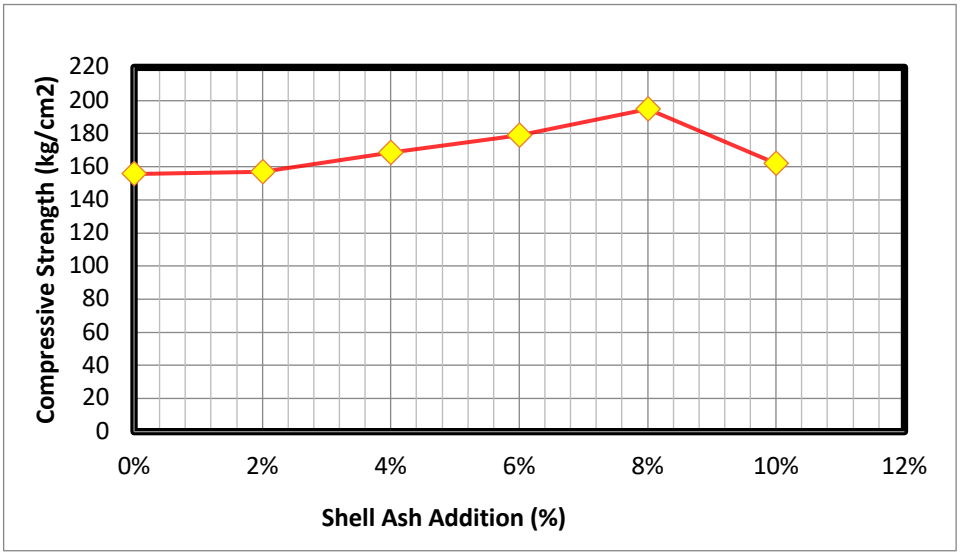

Figure 7. Relationship between the addition of palm kernel shell ash and compressive strength at 28 days

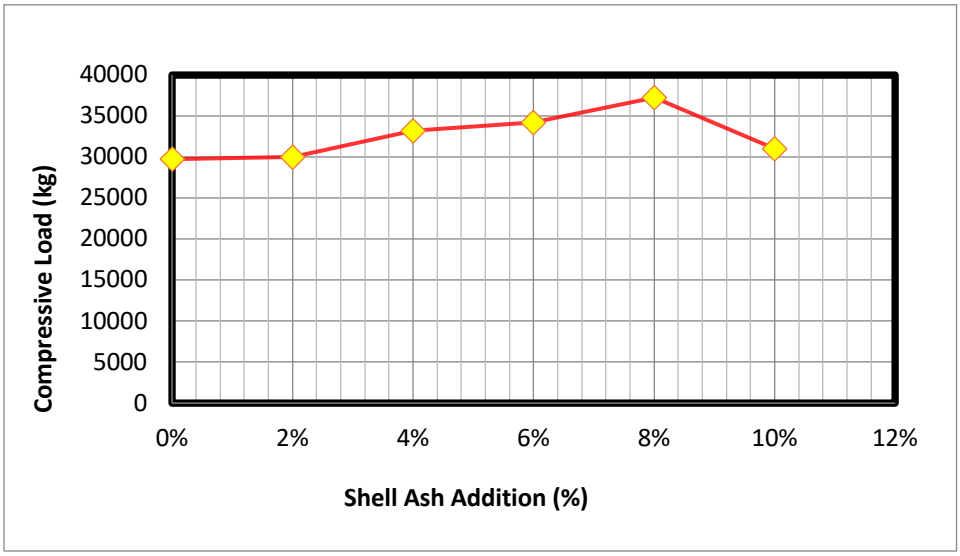

Figure 8. Relationship between the addition of palm kernel shell ash and compressive load at 28 days of age

It is also explained in Figures 7 and 8, at the planned age of 28 days, paving blocks with variations in the addition of palm shell ash experienced an increase in compressive strength. The increase in compressive strength ranged between 2-20 kg/cm2.

A greater increase in compressive strength (maximum) occurred with the addition of 8% palm shell ash, however after the addition of a 10% mixture variation, there was a decrease in the compressive strength of the paving block.

So from the results obtained at the age of 28 days, it can be concluded that the optimal value of adding palm shell ash occurs at a variation of 8% with a compressive strength value

of 194.82 kg/cm2. If referring to the SNI 03-0691-1996 regulation (specification of quality requirements for concrete bricks/paving blocks) then this value is included in the Quality IIIa/C category.

Combined Compressive Strength Test of Paving Block with Addition of Ash Palm Shells at 7, 14, 21 and 28 days of age

From table 5, the results of the combination of each test age will be made. The data below will show the comparison between the compressive strength of each additional mixture variation with the age of the sampling test object.

Table 5. Combined Results of Compressive Strength Testing

No.	Age	ACS 0% (Kg/cm ^{2})	ACS 2% (Kg/cm ^{2})	ACS 4% (Kg/cm ^{2})	ACS 6% (Kg/cm ^{2})	ACS 8% (Kg/cm ^{2})	ACS 10% (Kg/cm ^{2})
1.	07 Days	94.14	100.68	112.45	118.99	126.83	117.68
2.	14 Days	118.99	118.99	124.22	134.68	139.91	132.06
3.	21 Days	137.29	150.37	156.90	166.06	172.59	154.29
4.	28 Days	155.60	156.90	168.67	179.13	194.82	162.13

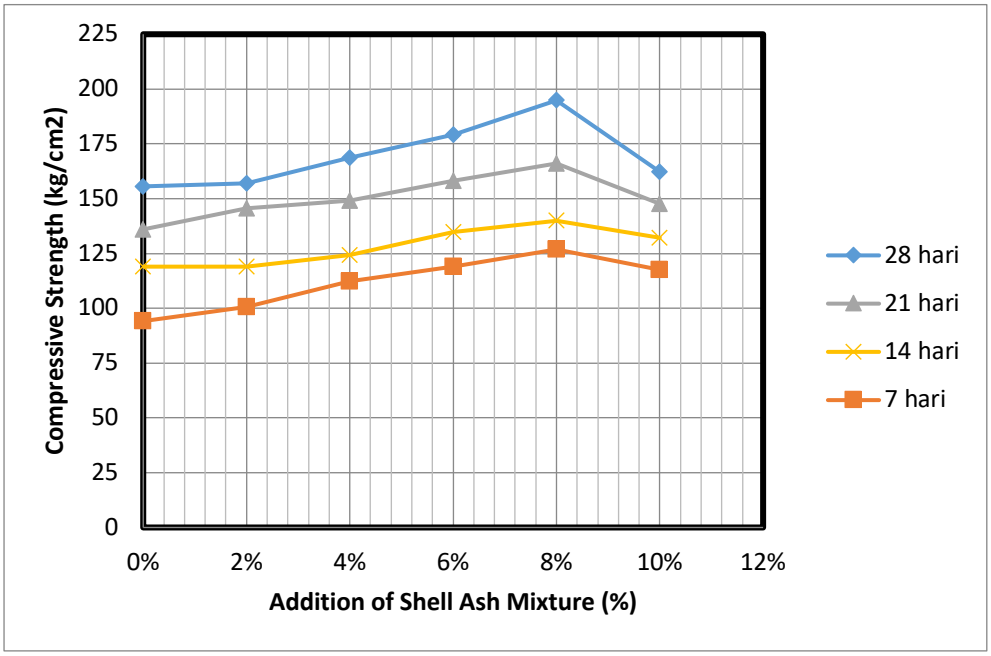

Figure 9. Relationship between Compressive Strength and the Addition of Mixture Variations.

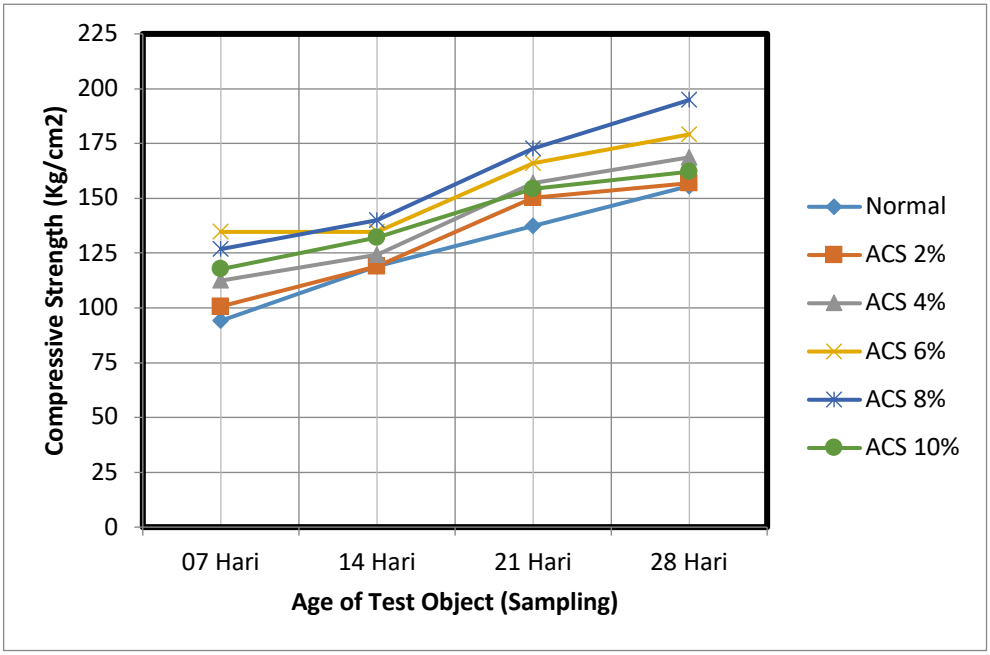

Figure 10. Relationship between Compressive Strength and Design Age of Test Specimens (Sampling).

From Figures 9 and 10, it is explained that the compressive strength results from each addition of the mixture variation obtained the optimal variation addition, namely the addition of palm shell ash by 8%. While in the 10% mixture variation there was a decrease in compressive strength. This occurred for each age of the sampling test object (7, 14, 21, and 28 days).

Meanwhile, the relationship between compressive strength and the age of the sampling test object can be concluded that, the compressive strength of the variation of the addition of palm shell ash mixture to the test object increased towards the design age. This was obtained from the age of 7 days to 28 days. And the maximum compressive strength results were obtained at the design age of 28 days, this occurred in each variation of the mixture.

CONCLUSION

The optimal increase in compressive strength of paving blocks by adding 8% palm shell ash content. While in the 10% mixture variation, the compressive strength of paving blocks decreased. This occurs for each age of the test object (age 7,14,21,28) days. The results of the compressive strength test of paving blocks on variations of the addition of palm shell ash mixture, paving blocks experienced an increase in the immersion age. This was obtained from the age of 7 days to 28 days. And the maximum compressive strength test results were obtained at the planned age of 28 days, this occurred in each variation of the mixture. Based on the regulations according to SNI 03-0691-1996, paving blocks with a mixture variation of 8% and at the age of 28 days are included in the Quality Class C/IIIa. The use of paving blocks based on this quality is usually used to receive light intensity loads.

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