JSE Journal of Science and Engineering, Vol. 3, No. 1 (page: 9-16)
e-ISSN: 2723-3944 July 2024
DOI: https://doi.org/10.30650/jse.v3i1.3984

Impact of Using Tenggarong Sand and Lightweight Brick Waste in the Production of Pavement Paving Blocks

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Abstract – The development of construction encourages increased development so as to create innovations in the development, one of which is used of road pavement materials which were originally dominated by asphalt, has now varied with paving blocks. Using waste as a mixture in making paving blocks is an alternative to creative and innovative products. In this case making paving blocks with brick waste, the waste increases along with the number of lightweight brick enthusiasts. The purpose article is to determine the strength value of paving blocks made from brick waste and tenggarong sand as a mixture of lightweight brick waste. The mixing ratio of cement and sand used was 1:6 with variations in the mixture of lightweight brick waste 0%, 25%, 50%, 75% and 100%. The tests carried out were water absorbtion and compressive strength. Data collection by testing in the laboratory on the materials used are sand tenggarong, cement three wheels and CLC lightweight brick waste. The results show that the most optimal percentage of the use of brick waste is at a percentage of 25% at the age of 28 days has a compressive strength value of 28.85 Mpa thus included in the quality of class B (parking lot). While the other percentages do not match between the compressive strength and the absorbtion value that has been determined. Research on compressive strength and water absorbtion of paving blocks can be the basis for further research such as testing the wear of paving blocks.

Keywords: inovation, paving blocks, brick waste

Submitted: 11 Juni 2024 - Revised: 27 July 2024 - Accepted: 29 July 2024

1. Introduction

In the age of globalization, the proliferation of construction has led to a significant increase in development. Breakthroughs in construction create new innovations in the development process. One example is the use of pavement materials, which was originally dominated by asphalt, has now varied with the increasingly common use of concrete bricks or paving blocks.

Paving block (concrete brick) is a combination of construction materials consisting of a mixture of Portland cement or other hydraulic adhesive materials, water, and aggregate, with or without the addition of other materials that affect its quality [1]. Paving blocks are used as floors outside buildings such as parks, parking lots, pedestrian areas and so on whose use must have good aesthetic power, in addition to shape and color, the style in the installation also does not go unnoticed. Installation of paving blocks can also be intended on the road body and can be used to replace the cover layer of asphalt mixture and cement concrete roads or other words semenisasi [2]. The process of making paving blocks must meet the criteria according to the purpose and function of its use. The quality of paving blocks or concrete bricks must meet the quality standards of SNI 03-0691-1996.

Tenggarong City is one of the cities and is the capital of Kutai Kartanegara Regency, East Kalimantan Province. The material that has a very large potential that comes from Tenggarong is Tenggarong sand. According to research conducted by Sentana in 2020 concluded that the physical examination of tenggarong sand has met the 2010 Bina Marga specifications [3]. From research conducted by Sundari in 2012, it is explained that the effect of concrete age on compressive strength values using fine aggregate tenggarong sand has met the quality requirements of K250 (20.75 Mpa) and K300 (24.90 Mpa) [4].

Lightweight brick is a type of brick that has pores with a lower specific gravity than brick in general, the specific gravity of lightweight brick is between 600-1600 kg/m3 depending on the mixture used [5]. In Indonesia, lightweight bricks were first produced by PT Hebel Indonesia in Karawang, West Java in 1995. At this time many people are using lightweight bricks as construction materials. This is because the use of lightweight bricks is easier and more practical so that it can save material and speed up the efficiency of work time.

There are two types of lightweight bricks that are commonly known, namely Autoclaved Aerated Concrete (AAC) and Cellular Lightweight Concrete (CLC) [6]. The difference between the two is the production process. AAC lightweight bricks are a type of cellular concrete in which the formation of air bubbles occurs due to the chemical reaction of aluminum paste that expands as in the process of making bread [7]. The raw material for making AAC lightweight bricks is silica sand which is pulverized to a small size. The drying process of AAC lightweight bricks uses a tube that has high pressure. On the other hand, CLC lightweight bricks have a separate air bubble making process, and the drying or curing is done naturally. In the CLC manufacturing process, a foaming agent is used that produces a very stable organic foam. During the mixing process, no chemical reaction occurs [8].

Various kinds of research have been carried out with the aim of obtaining material variation options so that the resulting paving blocks have optimal characteristics and are efficient in their use, such as studies using red brick and lime waste [9], plastic waste [10], silica sand, hazelnut shell ash waste [11], crushed stone waste [12], limestone [13], crum rubber [14] and many more.

As the demand for lightweight bricks increases, the productivity of lightweight bricks increases. This results in pieces of lightweight bricks that become waste and cannot be used. In this research, lightweight brick waste of Cellulaar Lightweight Concretee (CLC) type is utilized, which is taken from the remaining pieces that are not used so that they become garbage in a business that produces lightweight bricks of CLC type on Anang Hasyim Street, Samarinda City. The use of lightweight brick waste is used as an added material and a substitute for fine aggregate in the manufacture of paving blocks. In addition to lightweight brick waste in this study also used tenggarong sand as a mixture, tenggarong sand is obtained from the mahakam river flow located in Teluk Dalam Village, Tenggarong Seberang Subdistrict, Tenggarong City by suction and quarry. The underutilization of tenggarong sand as a material for making paving blocks is also the reason for its use as a mixture in this study.

In this research, it is hoped that lightweight brick waste can be utilized and can have a high selling value and lightweight brick waste processing can be resolved. Therefore, research is needed related to the use of lightweight brick waste with tenggarong sand to produce the best type of paving block classification.

The purpose of preparing this research is to determine the strength value of paving blocks made from lightweight brick waste and tenggarong sand as a mixture of lightweight brick waste and to provide in-depth knowledge about the utilization of tenggarong sand and lightweight brick waste in the process of making paving blocks. The main objective of this research is to present alternative construction materials and provide guidelines for future research.

2. Research Methods

Data collection is carried out by direct testing in the laboratory on the materials used, testing water absorption and compressive strength on the test specimens. The research method begins with preparing and testing the material to be used. From the results of material testing can be used as a basis for mixing materials or mix design continued with the manufacture and treatment of test objects and then testing the absorption and compressive strength of the test objects. The test results will be analyzed to get the conclusion of the research.

The process of making samples was carried out at the CLC lightweight brick factory on Anang Hasyim Street and sample testing in this study was carried out at the Civil Engineering Laboratory of Muhammadiyah University of East Kalimantan, Jalan Ir. H. Juanda, No. 15, Samarinda City. The fine aggregate used is sand from Tenggarong obtained from the mahakam river by suction and quarry located in Teluk Dalam village, Tenggarong Seberang sub-district, Tenggarong city. Light brick waste used is obtained from the remnants of the production of CLC type light brick waste factory on Anang Hasyim road. The cement used is cement with the Tiga Roda brand obtained from Toko Bersama Jaya Samarinda City. This paving block is made from lightweight brick waste and tenggarong sand as a mixture of lightweight brick waste. The mixing ratio of cement and sand used is 1:6 with variations in the mixture of lightweight brick waste 0%, 25%, 50%, 75% and 100%. Tests of test objects carried out are water absorption and compressive strength.

3. Results and Discussion

This paving block is made from lightweight brick waste and tenggarong sand as a mixture of lightweight brick waste. The mixing ratio of cement and sand used is 1:6 with variations in the mixture of lightweight brick waste 0%, 25%, 50%, 75% and 100%. Testing of test objects carried out is water absorption and compressive strength. Before the material is applied in the manufacture of paving block samples, the first step that needs to be done is to undergo a number of tests on the material itself. Testing of these materials is carried out at the Civil Engineering Laboratory of Muhammadiyah University of East Kalimantan. Some of the tests that are usually carried out include.

3.1. Fine Aggregate Testing

The fine aggregate used is a type of tenggarong sand that passes through sieve number 4. The series of fine aggregate test results can be seen in Table 1 below.

Table 1
Fine Aggregate Testing Results

Testing	Value	Unit	Standard Specification
Sludge Content	2,8	%	SNI-03-4142-1996
Modulus of Smoothness	1,58	%	SNI-T-15-1990-03

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Specific gravity	2,174	gr	SNI-1970-2008
Absorption	9,359	%	SNI-1970-2008
Volume Without Corner	1,315	gr/cm³	SNI-03-4841-1998
Volume With Corner	1,509	gr/cm³	SNI-03-4841-1998
Water Content	4,603	%	SNI-03-1971-1990
Humidity	5,459	%	ASTM C 556-89

Table 1 lists some of the test results for fine aggregate materials. The test results of materials that do not meet are absorption and volume testing without rojokan. The results of the absorption test did not meet because it exceeded the standard limits of the SNI 1970-2008 specification, this was due to the sand used at the time of testing in a dry state so that the absorption of water was relatively high, while the volume test without corners did not meet the standards because it was less than the standard specifications of SNI-03-4841-1998 due to the weighing process of the aggregate not being flat with the surface of the container and there were still cavities in the mold that were not filled with sand so that to prevent this from happening when filling the mold it must be done little by little and must be flat with the surface of the mold [15], [16], [17], [18], [19], [20]. From the fineness modulus number can be used to determine the sand gradation zone where the graph can be seen in Figure 1 below.

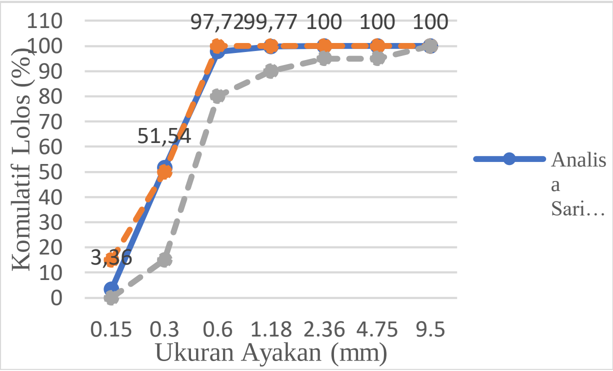

Figure 1. Aggregate Gradation Zone Chart

From Figure 1 above is a fine aggregate zoning chart where the fine aggregate used is included in gradation zone number 4 or fine sand category in accordance with SNI 03-2834-2000.

3.2. Cement Testing

The cement used is three-wheel cement with a weight of 50 kg obtained from Toko Bersama Jaya in Samarinda City. The series of cement test results can be seen in Table 2 below.

Table 2
Cement Testing Results

Testing	Value	Unit	Standard Specification
Volume Without Corner	1,176	gr/cm³	ASTM C188-89
Volume With Corner	1,257	gr/cm³	ASTM C188-89
Specific gravity	3,168	gr/cm³	SNI-15-2531-1991

In Table 2, the volume weight test data above recorded a value of 1.176 gr/cm³ before the corner and 1.257 gr/cm³ after the corner, the test results are based on ASTM C188-89. While the specific gravity test results have an average value of the two samples that have been tested, namely 3.168 gr/cm3. Thus the results of the cement specific gravity test are in accordance with the SNI 15-2531-1991 standard with an interval between 3.00 to 3.20 [19], [21].

The cement material also needs to be tested for normal consistency. To get the test results, it is also necessary to use the trial and error method to get a penetration value of 10 mm which can be seen in Table 3 below.

Table 3
Normal Consistency Testing Results

Cement Weight (gr)	Water Percentage (%)	Needle Drop (mm)
300	24 = 72 ml	5
300	26 = 78 ml	6
300	28 = 84 ml	10
300	30 = 90 ml	16
300	32 = 96 ml	18

In Table 3, the normal consistency test data shows the penetration values and water percentage as follows: 5 mm with 24% water, 6 mm with 26% water, 10 mm with 28% water, 16 mm with 30% water, 18 mm with 32% water. Penetration value of 10 with 28% water percentage. The normal consistency graph can be seen in Figure 1 below.

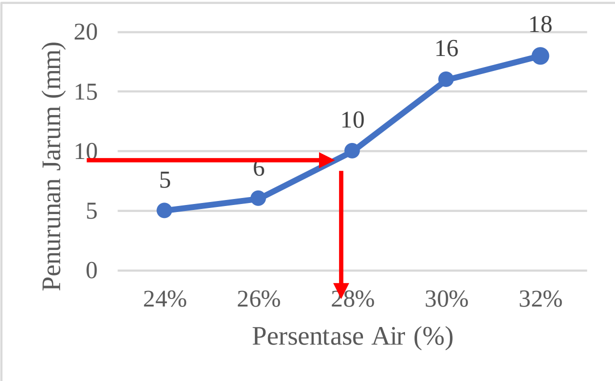

Figure 2. Normal Consistency Graph

In cement materials, it is also necessary to test the binding time or hard time. This test aims to determine the time required for the cement to harden. The results of the cement binding time test can be seen in Table 4 below.

Table 4
Binding Time Test Results

Drop Time (Minutes)	Decline (mm)
15	50

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30	45
45	44
60	31
75	29
90	16
105	12
120	5
135	2
150	0

By using the data from the binding time or hard time test results contained in Table 4, it can be used to determine the cement binding time graph which can be seen in Figure 2 below.

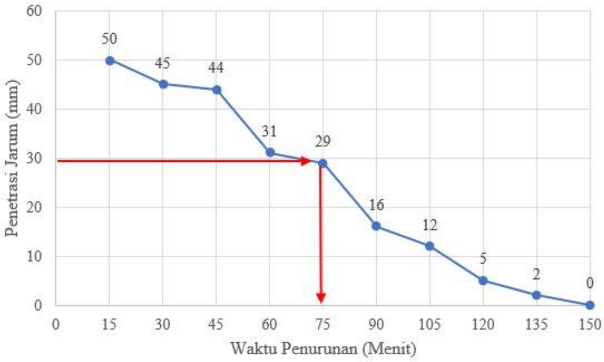

Figure 3. Grafik Waktu Ikat

Based on the data in Table 4 and Figure 4, the initial cement bond time graph can be identified when the needle drop reaches 29 mm after 75 minutes of testing, while the final bond time occurs when the vicat needle does not penetrate the cement paste at the 0 mm position after 150 minutes of testing.

3.3. Testing of Lightweight Brick Waste

In this research utilizing lightweight brick waste type Cellulaar Lightweight Concretee (CLC) taken from the remnants of pieces that are not used so that it becomes garbage in a business where the production of lightweight brick type CLC on Jalan Anang Hasyim Samarinda City. The use of lightweight brick waste is used as an added material and a substitute for fine aggregate in the manufacture of paving blocks. The series of test results of lightweight brick waste can be seen in Table 5 below.

Table 5.
Testing Results of Lightweight Brick Waste

Pengujian	Nilai	Satuan	Standar Spesifikasi
Modulus of Smoothness	1,74	%	SNI-T-15-1990-03
Specific gravity	1,469	gr	SNI-1970-2008
Absorption	42,262	%	SNI-1970-2008
Volume Without Corner	0,796	gr/cm³	SNI-03-4841-1998
Volume With Corner	1,105	gr/cm³	SNI-03-4841-1998
Water Content	30,552	%	SNI-03-1971-1990
Humidity	23,398	%	ASTM C 556-89

From Table 5, several test results of lightweight brick waste were recorded. The results of the fineness modulus test show a number of 1.74 so that these results have met the SK-SNI-T-15-1990-03 standard with an interval between 1.50 -3.80. In the specific gravity test, the volume weight of both volume weight without rojokan and folume weight with rojokan does not meet the specification standards because the lightweight brick waste has a mass that is much lighter than other materials (fine aggregate). From the results of the absorption test, the moisture content and humidity do not meet the specification standards. This happens because lightweight brick waste has a high water-absorbing property so that the moisture content contained therein is also high [15], [16], [17], [18], [19], [20].

The fineness modulus number can be used to determine the gradation zone of lightweight brick waste, the graph of which can be seen in Figure 4 below.

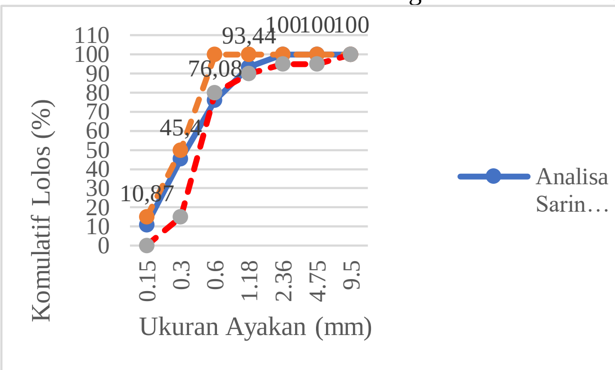

Figure 4. Lightweight Brick Waste Gradation Zone Chart

From Figure 4 above is a zoning graph of fine aggregates used in gradation zone number 4 or fine sand category in accordance with SNI 03-2834-2000.

3.4. Mix Design Material

Material mixing was done manually by mixing fine aggregate, waste lightweight bricks, cement and water according to the dosage. The sand cement composition ratio used was 1:6. The mixture of materials used is Tenggarong sand and lightweight brick waste as an added material. The use of lightweight brick waste as an added material in the manufacture of paving blocks uses a percentage of 0%, 25%, 50%, 75% and 100% of the weight of sand. The paving block mold used is hexagon or hexagonal. The following is the calculation of the mix design material used.

Volume of test piece (v) = 3.a.b.h
= 3 .10 x 11,5 x 6
= 2070 cm^3

Mixing Factors = 1,2 x 2070
= 2484 cm^3

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Requirement of sand and cement with ratio 1:6

Cement Requirement = 1/7 x 2484
= 354,857 cm^3
= 354,857 x bvs
= 354,857 x 1,22
= 431,861 gr

Sand Requirement = 6/7 x 2484
= 2129,143 cm^3
= 2129,143 x bvp
= 2129,143 x 1,31
= 2789,18 gr

Description:
a = Mold width
b = Mold length
h = Mold depth
bvs = Cement Volume Weight
bvp = Weight of Sand Volime

3.5. Absorption Testing

Absorption testing on paving blocks aims to determine the percentage of the ability of paving blocks to absorb water in each variation. The results of the absorption test data can be seen in Table 6 below.

Table 6
Absorption Testing Results

Testing	0%	25%	50%	75%	100%	Unit
Weight of Test Item Before Soaking	3640	3250	2910	2940	2900	gr
Weight of Test Item After Soaking	3490	3290	2970	2840	2660	gr
Weight of Test Item After Oven	3380	3120	2770	2600	2400	gr
Absorption	3,152	5,167	6,734	8,451	9,774	%

From the data of paving block absorption test results in Table 6, the following absorption values were recorded. 0% variation with absorption value of 3.152%, 25% variation with absorption value of 5.167%, 50% variation with absorption value of 6.734%, 75% variation with absorption value of 8.451% and 100% variation with absorption value of 9.774%. From the test results, the higher the use of lightweight brick waste in paving blocks, the higher the absorption value of paving blocks. Using the results of the paving block absorption test can be used to determine the usefulness of paving blocks in accordance with SNI 03-0691-1996 standards contained in Table 7 below.

Table 7
Paving Block Quality Water Absorption Requirements

Type	Usability	Max Average Moisture Content (%)
A	Road Pavement	3
B	Car Parking Lot	6
C	Pedestrians	8
D	City Park	10

By referring to Table 7, it can be used to determine that the 0% variation with an absorption value of 3.152% is included in the quality of type B (Car Park), 25% variation with an absorption value of 5.167% is included in the quality of type B (Car Park), 50% variation with an absorption value of 6.734% is included in the quality of type C (Pedestrian) while for 75% variation with an absorption value of 8.451% and 100% variation with an absorption value of 9.774% is included in the quality of type D (City Park) [1].

3.6. Compressive Strength Testing

Testing the compressive strength of the paving block aims to determine the strength of the paving block. In addition, compressive strength testing on paving blocks also aims to determine the quality and usefulness of paving blocks. The results of compressive strength testing on paving blocks for 3 days can be seen in Table 8. In the table of compressive strength test results there are test object codes such as S1-3-0% which means sample 1 with an age of 3 days and has a percentage of light brick waste of 0%.

Table 8
Compressive Strength Testing Results for 3 Days

Test Item Code	Area of Stress Field	Test Item Weight	Maximum Load	Compressive Strength	Average
	mm²	gr	N	Mpa	Mpa
S1-3-0%	3435,96	3640	74100	21,57	22,06

e-ISSN: 2723-3944

S2-3-0%	3435,96	3490	86300	25,12	
S3-3-0%	3435,96	3660	67000	19,50	
S1-3-25%	3435,96	3350	58700	17,08	
S2-3-25%	3435,96	3390	55800	16,24	17,74
S3-3-25%	3435,96	3450	68400	19,91	
S1-3-50%	3435,96	3050	44000	12,81	
S2-3-50%	3435,96	2910	43800	12,75	14,69
S3-3-50%	3435,96	3020	63600	18,51	
S1-3-75%	3435,96	2940	57100	16,62	
S2-3-75%	3435,96	2980	40200	11,70	13,76
S3-3-75%	3435,96	2970	44500	12,95	
S1-3-100%	3435,96	2810	51400	14,96	
S2-3-100%	3435,96	2880	75500	21,97	19,52
S3-3-100%	3435,96	2900	74300	21,62	

From the results of the compressive strength test for 3 days in Table 21, it was recorded that the 0% variation had a compressive strength of 22.06 Mpa, the 25% variation had a compressive strength of 17.74 Mpa, the 50% variation had a compressive strength of 14.69 Mpa, the 75% variation had a compressive strength of 13.76 Mpa, and the 100% variation had a compressive strength of 17.58 Mpa. The highest compressive strength is at 0% percentage with a value of 22.06 Mpa while the lowest compressive strength is at 75% percentage with a value of 13.76 Mpa. The results of the compressive strength test on paving blocks for 7 days can be seen in Table 9 below.

Table 9
Compressive Strength Testing Results for 7 Days

Test Item Code	Area of Stress Field	Test Item Weight	Maximum Load	Compressive Strength	Average
	mm²	gr	N	Mpa	Mpa
S1-7-0%	3435,96	3290	107600	31,32	
S2-7-0%	3435,96	3380	110500	32,16	30,99
S3-7-0%	3435,96	3560	101300	29,48	
S1-7-25%	3435,96	3440	87400	25,44	
S2-7-25%	3435,96	3250	78700	22,90	24,10
S3-7-25%	3435,96	3220	82300	23,95	
S1-7-50%	3435,96	3370	60100	17,49	
S2-7-50%	3435,96	3360	67500	19,65	18,62
S3-7-50%	3435,96	3390	64300	18,71	
S1-7-75%	3435,96	3330	50300	14,64	
S2-7-75%	3435,96	3240	56400	16,41	15,90
S3-7-75%	3435,96	3230	57200	16,65	
S1-7-100%	3435,96	3300	60400	17,58	
S2-7-100%	3435,96	3240	63600	18,51	17,68
S3-7-100%	3435,96	3210	58200	16,94	

From the results of the compressive strength test for 7 days above, it was recorded that the 0% variation had a compressive strength of 30.99 Mpa, for the 25% variation it had a compressive strength of 24.10 Mpa, for the 50% variation it had a compressive strength of 18.62 Mpa, for the 75% variation it had a compressive strength of 15.90 Mpa, for the 100% variation it had a compressive strength of 18.35 Mpa. The highest compressive strength is at 0% percentage with a value of 30.99 Mpa while the lowest compressive strength is at 75% percentage with a value of 15.90 Mpa. The results of the compressive strength test on paving blocks for 28 days can be seen in the following Table 10

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Table 10
Compressive Strength Testing Results for 28 Days

Test Item Code	Area of Stress Field	Test Item Weight	Maximum Load	Compressive Strength	Average
	mm²	gr	N	Mpa	Mpa
S1-28-0%	3435,96	3480	117900	34,31	
S2-28-0%	3435,96	3610	121400	35,33	34,01
S3-28-0%	3435,96	3700	111300	32,39	
S1-28-25%	3435,96	3410	101600	29,57	
S2-28-25%	3435,96	3390	97600	28,41	28,85
S3-28-25%	3435,96	3400	98200	28,58	
S1-28-50%	3435,96	3230	91500	26,63	
S2-28-50%	3435,96	3100	99000	28,81	26,48
S3-28-50%	3435,96	3150	82500	24,01	
S1-28-75%	3435,96	3060	61300	17,84	
S2-28-75%	3435,96	3180	78300	22,79	20,76
S3-28-75%	3435,96	3080	74400	21,65	
S1-28-100%	3435,96	3020	67400	19,62	
S2-28-100%	3435,96	2770	58300	16,97	18,74
S3-28-100%	3435,96	3020	67500	19,65	

From the results of the compressive strength test for 28 days in Table 23, it is recorded that the 0% variation has a compressive strength of 34.01 Mpa, for the 25% variation it has a compressive strength of 28.85 Mpa, for the 50% variation it has a compressive strength of 26.48 Mpa, for the 75% variation it has a compressive strength of 20.76 Mpa, for the 100% variation it has a compressive strength of 18.74 Mpa. The highest compressive strength is at 0% with a value of 34.01 Mpa while the lowest compressive strength is at 100% with a value of 18.74 Mpa.

From the data on the compressive strength test results previously discussed, it can be used to create a compressive strength graph on the paving block which can be seen in Figure 5 below.

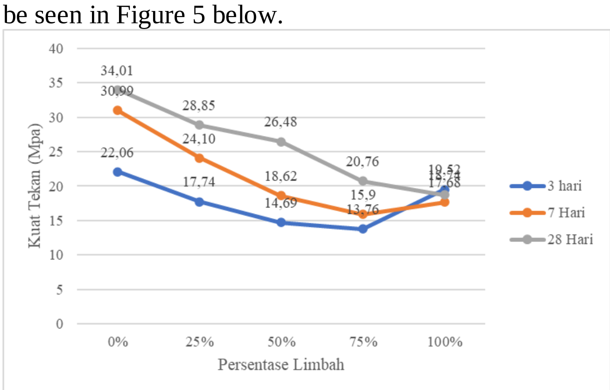

Figure 5 Paving Block Compressive Strength Chart

From the compressive strength graph in Figure 5, it is noted that the highest compressive strength is at 0% percentage at the age of 28 days with a value of 34.01 Mpa and the lowest compressive strength is at 75% percentage at the age of 3 days with a value of 13.76 Mpa. The results of the compressive strength test at the age of 3 and 7 days there was a decrease in compressive strength from the percentage of 0% to 75% this occurred because the higher the percentage of addition of lightweight brick waste the lower the compressive strength value, but at a percentage of 100% it increased due to the nature of lightweight brick waste without a mixture of sand which, when pressed, will solidify. As for the age of 28 days, there is a decrease in compressive strength from 0% to 100% percentage. From the results of the strength test, the most optimal percentage of the use of lightweight brick waste is at a percentage of 25% at the age of 28 days, which has a compressive strength value of 28.85 Mpa, thus entering the quality of class B (Parking Lot).

From the compressive strength chart of the paving block, it was noted that the percentage of 100% compressive strength produced at the three sample ages did not have a significant difference. The compressive strength value of 100% percentage with a sample age of 28 days has a compressive strength of 19.52 Mpa, 7 days old has a compressive strength of 17.68 and 3 days old has a compressive strength of 18.74 Mpa. The compressive strength of the 3-day age is higher than that of the 7-day age, thus the percentage of 100% lightweight brick waste as a material for making paving blocks is not recommended.

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4. Conclusion

From the discussion that has been discussed in the previous chapters, it can be concluded that the absorption test recorded 0% variation with an absorption value of 3.152% and 25% variation with an absorption value of 5.167% included in the quality of type B (Car Parking Lot), 50% variation with an absorption value of 6.734% included in the quality of type C (Pedestrian) while for 75% variation with an absorption value of 8.451% and 100% variation with an absorption value of 9.774% included in the quality of type D (City Park). The increase in water absorption in paving blocks is getting higher as the percentage of waste used increases.

From the test results, the most optimal percentage of the use of lightweight brick waste is at a percentage of 25% at the age of 28 days, which has a compressive strength value of 28.85 Mpa, thus entering the quality of class B (Parking Lot). While the other percentages do not match the compressive strength with the absorption value set in the SNI 03-0691-1996 standard.

Reference

[1] Badan Standarisasi Nasional, Standar Nasional Indonesia *SNI-03-0691-1996 Tentang Bata Beton (Paving Block)*

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e-ISSN: 2723-3944