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The Effect of Lime Addition on the Compressive Strength Improvement of Paving Blocks Write

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Abstract: *Paving blocks are made by mixing the composition of cement, sand, water, and or other additives, then pressure is applied with a certain intensity. The use of paving blocks is becoming increasingly widespread, prompting the search for alternative additives that can enhance compressive strength. Lime is selected as an additional alternative material in the paving block mixture. Lime is relatively easy and cheap because this material is abundant in Indonesia, which spreads to various islands, namely Java, Sumatra, and Irian Jaya. Hence, the availability of this material is very much. This study aims to determine the effect of adding lime to the compressive strength of paving blocks. The composition of the mixture in this study is the quality of class D. The compressive strength of this class D is compared to the compressive strength of the paving block with the addition of lime. The percentage of lime addition is 2%, 4%, 6%, 8%, and 10% to the weight of cement. The cement used is PCC (Portland Cement Composite) type, and the test specimen is printed in a hexagonal shape using manual tools. The results of laboratory tests showed that the sand sludge content and grain fineness modulus (MHB) were satisfactory. The maximum increase in compressive strength occurs with the addition of 8% lime. According to SNI-03-0691-1996, the compressive strength of 8% lime is classified as class C quality. Meanwhile, the addition of 10% lime at the age of 28 days resulted in a decrease of 17% in the compressive strength of the addition of 8% lime.*

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INTRODUCTION

The use of paving blocks is increasingly used, including in special places that require more strength to withstand secondary loads, such as in corner areas, bus stops, parking areas, ports, as well as to use pavement in certain areas such as roads in residential/shopping areas, ports, walkways/alleys, sidewalks, roads in tourist areas, office yards. Paving blocks are considered more practical and economical compared to the use of reinforced concrete (rigid) pavement. Paving blocks are easier to install and work with, easy to dismantle without the need for heavy equipment, able to withstand loads within certain limits, and their construction is relatively durable and has beautiful shapes and colors. Paving blocks can be produced either manually (human power) or by machine tools. In general, paving blocks are produced by a machine that has a higher quality than those that are printed manually.

Based on this aspect of practicality and economic value, the use of paving blocks among the community is increasing. Therefore, efforts are needed to improve the quality

of paving blocks by looking for alternatives to the use of additives such as lime, fly ash, bottom ash, rice husk ash, and others. It is hoped that with the use of this additive, in addition to the quality of paving blocks and the quantity increases, the price will be affordable for many people.

In this study, the author is interested in adding lime to the paving block mixture. Limestone is one of the potential rocks that are abundant in Indonesia, spreading from the mountains of Java, Sumatra and Irian Jaya. Therefore, lime additives are relatively easy and cheap to get. It is hoped that the addition of lime to the paving block mixture can increase the compressive strength.

Paving blocks are made by mixing the composition of composite cement (binding agent), sand (filler), water (material to mix) and lime (additive) in a ratio until it is evenly distributed. The paving block printing process is carried out with manual tools. Compressive strength testing was performed at 7, 14, 21 and 28 days of age. This study was conducted to determine the effect of adding lime where there is an increase or decrease in compressive strength. The variation in the percentage of lime addition in this study includes 2%, 4%, 6%, 8% and 10% to the amount of cement. The results of the paving block compressive strength test without the addition of chalk (normal) will be compared with the compressive strength test of the paving block with the addition of chalk. So that the optimal percentage of lime is obtained where the maximum compressive strength occurs.

LITERATURE REVIEW

According to SNI 03-0691-1996, paving block (concrete bricks) are a building material composition made from a mixture of Portlad cement or similar hydraulic adhesive, water, and aggregates, with or without other materials that do not reduce the quality of the concrete bricks.

Concrete bricks have many advantages, such as easy installation, good adhesion, weather resistance, low maintenance costs, and the ability to withstand certain loads.

Limestone is a fine-grained white sedimentary rock containing calcium minerals. The three main compounds that make up lime are calcium carbonate, calcium oxide, and calcium hyroxide. Limestone can be mixed with a magnesium mineral called dolomite. Over millions of years, this layer becomes rock through geological processes. Limestone is avery useful material in all forms of human activity and is relatively inexpensive.

It's most common use is in the construction sector. Limestone also has the property of hardening easily, making it widely used in the construction industry. The advantage of using limestone waste is that this material is easily obtained and also contains the chemical compound CaCo3 (calcium carbonate), which is a good content for building materials.

RESEARCH METHOD

2.1. Research Location and Time

This research was carried out in several different locations. Material testing is carried out in the Medan State Polytechnic laboratory, the paving block printing process is carried out at CV. Sarah Idola, while the compressive strength test was carried out at the Medan State Polytechnic Laboratory. The printing of the test specimen was carried out on August 3, 2025, while the last compressive strength test was carried out on August 31, 2025, exactly at the age of 28 days of paving blocks.

2.2. Materials and Equipment

2.2.1. Ingredients

The materials used in the manufacture of paving blocks include:

1. PCC Cement (Red and White Cement)
2. Sand as a fine aggregate
3. Lime $CaCO_3$
4. Water

2.2.2. Equipment

The equipment used during the study is as follows:

- Digital scales: for weighing materials such as cement, sand, and lime.
- Strainer/sieve: for fineness analysis of fine aggregates.
- Cement spoon: for stirring and transferring the mixture.
- Container/bucket: as a mixing place for materials.
- Paving block mold: hexagonal shape, size 16 cm × 9.5 cm × 6 cm.
- Measuring cup: to measure the volume of water.
- Pressure test equipment: to measure the compressive strength of paving blocks.

2.3. Material Preparation and Testing

2.3.1. Sieve Analysis (Grain Fineness Modulus)

The analysis was performed to determine the grain size distribution of fine aggregates. The testing procedure includes:

1. Weigh 1000 grams of dry sand.
2. Dry in the oven for 24 hours.
3. Arrange the strainer by size from large to small.
4. Sieve with the machine for 15 minutes.
5. Weigh the remaining material in each filter.
6. Calculates the retained and pass percentage to determine the fineness modulus of the grain.

2.3.2. Sand Sludge Rate Test

This test is carried out to determine the percentage of sludge content in the sand. The procedure is as follows:

1. Dry 1000 grams of sand at a temperature of ±110°C for 24 hours.
2. Wash the sand with a No. 200 sieve and water until the washing water becomes clear.
3. Dry the sand again and weigh to determine the difference in weight.

2.4. Mix Planning

This study used five variations of lime content as an additive, namely 2%, 4%, 6%, 8%, and 10% of the weight of cement. One variation of normal paving block (without lime) is used as a control (class D), with a minimum compressive strength target of 12.5 MPa.
Mixed Composition:

- Comparison of main material: cement : sand = 1 : 8
- Total samples: 48 test pieces (8 samples for each variation, including controls)
- Material requirements for 8 samples:
  1. Semen: 2,5 kg
  2. Sand: 20 kg
  3. Lime:
     - 2% = 50 gram

- 4% = 100 gram
- 6% = 150 gram
- 8% = 200 gram
- 10% = 250 gram

2.5. Paving Block Printing and Testing

2.5.1. Printing Process

The steps of paving block printing are:

1. Material preparation: sand, cement, lime, and water are weighed as needed.
2. Mixing:
   - Dry mixtures (sand, cement and lime) are homogenized in advance.
   - Water is added gradually until the mixture is homogeneous.
3. Printing:
   - The first layer (Pc:Ps = 1:2) is poured into a 1–1.5 cm thick mold.
   - The main layer (Pc:Ps = 1:8) is added until the full mold.
   - Pressing is done manually using an iron lever.
   - After molding, the paving block is removed and placed in the shade.
4. Treatment: it is done by the soaking method to maintain moisture during the hydration process.

2.5.2. Compressive Strength Testing

Compressive strength testing was performed at 7, 14, 21, and 28 days of age, using 2 samples per variation, respectively. Testing steps:

1. The test piece is weighed first.
2. Placed in the center of the pressure testing machine.
3. The load is applied gradually until the test piece is cracked or damaged.
4. The maximum load is recorded when the needle stops moving.
5. The compressive strength value is calculated based on the surface area and the maximum load received.

2.6. Research Series

In general, the stages in this study consist of:

1. Preparation and testing of materials.
2. Mixing and printing of paving blocks.
3. Treatment of test objects.
4. Compressive strength testing at 7, 14, 21, and 28 days of age.

Processing and analysis of test results.

RESULT AND DISCUSSION

3.1. Material Testing

The tests carried out on fine aggregates are two types, namely sludge content testing and sieve analysis.

3.1.1. Sand Sludge Test Results

Sand sludge level testing was carried out with 2 samples; the following test results are:

Table 1. Sand Silt Content Test Results

Description		Sample I	Sample II
Initial Sand Weight (W1)	(gr)	500	500
Weight Dry sand after ovening (W2)	(gr)	476	485
Mud Rate (KL)	(%)		
KL = (W1 - W2)/ W1 x 100%		4.8	3
Average		3.9	

Sludge rate (sample I)

$$= \frac{W1-W2}{W1} \times 100\%$$

$$= \frac{500-476}{500} \times 100\%$$

= 4,8% (smaller than 5%)

The results of the sand sludge level testing sample I are eligible.

Sludge rate (sample II)

$$= \frac{W1-W2}{W1} \times 100\%$$

$$= \frac{500-485}{500} \times 100\%$$

= 3,0 % (smaller than 5%)

The results of the sand sludge level testing sample II are eligible. Average sand sludge content is 3.9% (qualified)

According to ASTM C33-86, the permissible sludge content limit for sand is <5%. The results of the tests carried out obtained a sand sludge content of 3.9%. This sand meets the ASTM C33-86 standard, meaning that sand is suitable for paving block mixes.

3.1.2. Sand Sieve Test Results

The following are the results of the sand sieve test as follows.

Table 2. Sand Sieve Analysis Results

Strainer No.		Retained Weight (gr)		% retained weight		Average	% cumulative brt trtahan	% cumulative brt passed
		I	II	I	II			
No. 4	4,75mm	25	30	2.5	3.0	2.8	2.75	97.25
No. 8	2,36mm	37	48	3.7	4.8	4.3	7.00	93.00
No. 16	1,18mm	67	70	6.7	6.9	6.9	13.85	86.15
No. 30	0,60mm	326	320	32.6	32.3	32.3	46.15	53.85
No. 50	0,30mm	487	465	48.7	46.5	47.6	93.75	6.25
No100	0,15mm	43	41	4.3	4.1	4.2	97.95	2.05
PAN		15	26	1.5	2.6	2.1	100.0	0.0
TOTAL		**1000**	**1000**				**361.45**	

$$MHB = \frac{\%\ \text{Cumulative Retained Weight}}{100} \text{ x } 100\%$$

$$MHB = \frac{361,5}{100} \text{ x } 100\%$$

MHB = 3,61 (Qualify)

Based on the MHB value, sand is classified into 3 types, namely:

- Fine sand = 2,2 < MHB < 2,8
- Medium sand = 2,8 < MHB < 3,2
- Coarse sand = 3,2 < MHB < 3,8

The standard for grain fineness modulus (MHB) is 1.5 - 3.8. The results of the tests carried out obtained MHB of 3.61. This sand meets the SK-SNI-S-04-1989-F standard, which means that sand is suitable for paving block mixtures. This sand is classified as a type of coarse sand.
The distribution of grain size or better known as gradation, this sand is included in zone 1, can be seen in the following table.

Table 3. Comparison of Cumulative Passing Weight Percentages with Sieve Sizes

Sieve (mm)	% cumulative Weight Loss	Zone 1	
		Under	Above
10	97.25	100	100
4.8	93.00	90	100
2.4	86.15	60	95
1.2	53.85	30	70
0.6	6.25	15	34
0.3	2.05	5	20
0.15	0.00	0	10

A graph of the relationship between the size of the sieve and the cumulative percentage of passing the sieve can be seen in figure 1.

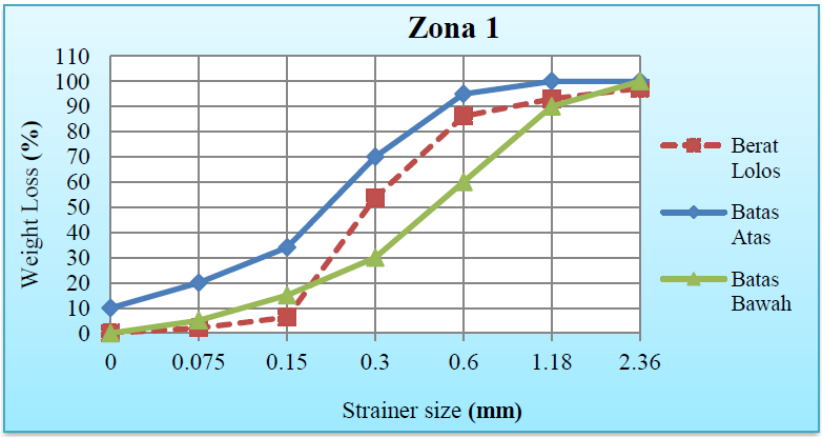

Figure 1. Relationship Between Sieve Size and Cumulative Passing Percentage of Sand

From figure 1, it can be seen that the red line shows the data on the weight of the sand passing in the upper and lower limits. When compared to zones 2, 3, and 4, the percentage of sand weight that passes the sieve is more precisely included in zone 1 (coarse sand).

3.2. Compressive Strength Testing of Paving blocks

The compressive strength achieved is the ratio between the compressive load and the cross-sectional area.

$$\sigma = \frac{P}{A}$$

where:

P = Press load (KN)
A = cross-sectional area of paving block (cm^2)

The size of the paving block printed in this study was p = 16 cm, l = 9.5 cm and t = 6 cm. The shape of the paving block is hexagonal/hexagonal. Each test age of 7, 14, 21 and 28 days consists of 2 samples each.

To calculate the surface area of paving blocks, namely:

L. segi-3 = (1/2 x a x t) x 2
= (1/2 x 8 x 4,75)x2
= 38,24 cm^2

Square area = p x l
=16 x 9,5
=152,95 cm^2

hence, the total area = Triangle Area + Square Area
= 38,24 + 152,95
= 191,19 cm^2

So the surface area of this hexagonal paving block is 191.19 cm^2.

So the unit for compressive strength achieved by paving blocks (σ) is kg/cm^2.

3.2.1. 7-Day Tensile Strength Test Results

The total number of 7-day lifespan test specimens is 12 pieces, 2 pieces each for each mixture variation. The results of the average compressive strength test of 7 days can be seen in table 4.

Table 4. Compressive Strength Test Results at 7 Days

No.	Test Object Name	Print Date	Test Date	Press Load (kg)	Compressive Strength (kg/cm2)
1	PB Normal	3-Aug-15	10-Aug-15	17750	92.84
2	PB Kapur 2%	3-Aug-15	10-Aug-15	20250	105.91
3	PB Kapur 4%	3-Aug-15	10-Aug-15	22500	117.68
4	PB Kapur 6%	3-Aug-15	10-Aug-15	23750	124.22
5	PB Kapur 8%	3-Aug-15	10-Aug-15	25250	132.06
6	PB Kapur 10%	3-Aug-15	10-Aug-15	23000	120.29

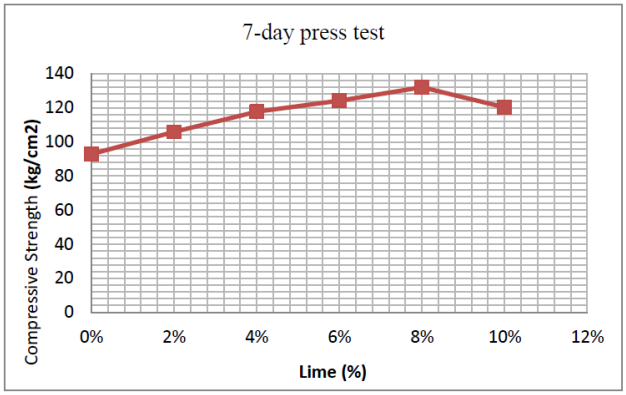

Figure 2. Relationship Between Compressive Strength and Lime Addition at 7 Days

From picture 2. It can be concluded that the compressive strength of paving blocks aged 7 days with the addition of 2%, 4%, 6% and 8% lime experiences a continuous increase in compressive strength from normal quality. The compressive strength of the addition of lime from 2% to 10% lime at the age of 7 days, the quality of the paving block is still class D.

- The magnitude of the increase in the compressive strength of the addition of lime by 2% compared to the normal compressive strength is 14.08%
- The magnitude of the increase in the compressive strength of the addition of lime by 4% compared to the normal compressive strength is 26.76%.
- The magnitude of the increase in the compressive strength of the addition of lime by 6% compared to the normal compressive strength is 33.80%.
- The increase in the compressive strength of the addition of lime by 8% compared to the normal compressive strength is 42.24%.

The addition of 10% lime experienced a decrease in compressive strength from the addition of 8% lime, where a decrease in compressive strength was 9%.

3.2.2. Compressive Strength Test Results 14 Days

The total number of 14-day lifespan test specimens is 12 pieces, 2 pieces each for each mixture variation. The results of the compressive strength test mean 14 days of age, can be seen in table 5.

Table 5. Compressive Strength Test Results at 14 Days

No.	Test Object Name	Print Date	Test Date	Press Load (kg)	Compressive Strength (kg/cm2)
1	PB Normal	3-Aug-15	18-Aug-15	23000	120.29
2	PB Kapur 2%	3-Aug-15	18-Aug-15	24000	125.52
3	PB Kapur 4%	3-Aug-15	18-Aug-15	24750	129.45
4	PB Kapur 6%	3-Aug-15	18-Aug-15	26500	138.60
5	PB Kapur 8%	3-Aug-15	18-Aug-15	27500	143.83
6	PB Kapur 10%	3-Aug-15	18-Aug-15	26500	138.60

The highest compressive strength occurs in the addition of 8% lime, which is 143.84 kg/cm^2 (equivalent to 11.93 Mpa).

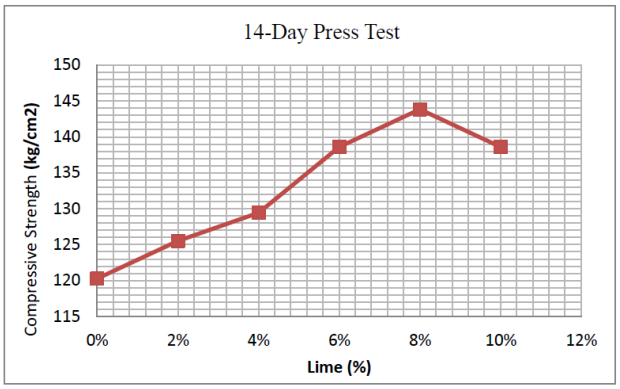

Figure 3. Relationship Between Compressive Strength and Lime Addition at 14 Days

Figure 3. shows the compressive strength of the paving block at 14 days of age, with an increase in compressive strength compared to the age of 7 days. Each addition of lime variations is continuously improved. The peak of compressive strength occurs with the addition of 8% lime. However, the addition of 10% lime experienced a decrease in compressive strength by 3.63% compared to the compressive strength of 8% lime.

The compressive strength of adding lime from 2% to 10% lime at the age of 14 days, the quality of paving blocks is still class D, where the quality of this class is used for gardens.

3.2.3. Compressive Strength Test Results 21 Days

The total number of test specimens for the 21-day test age was 12 pieces, 2 pieces each for each mixture variation (2%, 4%, 6%, 8% and 10% lime addition). The results of the average pressure strength test of 21 days can be seen in Table 6.

Table 6. Compressive Strength Test Results at 21 Days

No.	Test Object Name	Print Date	Test Date	Press Load (kg)	Compressive Strength (kg/cm2)
1	PB Normal	3-Aug-15	24-Aug-15	26500	138.68
2	PB Kapur 2%	3-Aug-15	24-Aug-15	28250	147.75
3	PB Kapur 4%	3-Aug-15	24-Aug-15	29500	154.29
4	PB Kapur 6%	3-Aug-15	24-Aug-15	31250	163.44
5	PB Kapur 8%	3-Aug-15	24-Aug-15	32750	171.29
6	PB Kapur 10%	3-Aug-15	24-Aug-15	28750	150.37

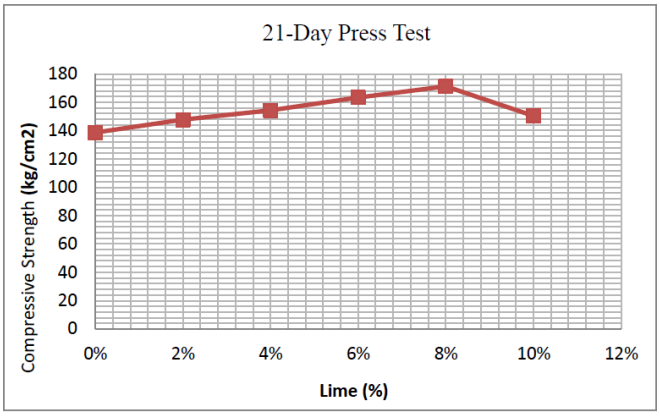

Figure 4. Relationship Between Compressive Strength and Lime Addition at 21 Days

Figure 4. shows that the compressive strength of the paving block at the age of 21 days has increased the compressive strength compared to the age of 14 days. An increase in compressive strength occurs continuously with the addition of lime by 2% - 8%. Meanwhile, the addition of 10% lime experienced a decrease in compressive strength by 12.21% compared to the compressive strength of 8% lime. The compressive strength of adding lime from 2% to 10% lime at the age of 21 days, the quality of paving blocks is also still class D.

3.2.4. 28-Day Tensile Test Results

The total number of test specimens aged 28 days is 12 pieces, 2 pieces each for each mixture variation. The results of the compressive strength test mean the age of 28 days, can be seen in Table 7.

Table 7. Compressive Strength Test Results at 28 Days

No.	Test Object Name	Print Date	Test Date	Press Load (kg)	Compressive Strength (kg/cm2)
1	PB Normal	3-Aug-15	31-Aug-15	29250	152.98
2	PB Kapur 2%	3-Aug-15	31-Aug-15	30750	160.83
3	PB Kapur 4%	3-Aug-15	31-Aug-15	33250	173.90
4	PB Kapur 6%	3-Aug-15	31-Aug-15	36250	189.59
5	PB Kapur 8%	3-Aug-15	31-Aug-15	39250	205.28
6	PB Kapur 10%	3-Aug-15	31-Aug-15	32500	169.98

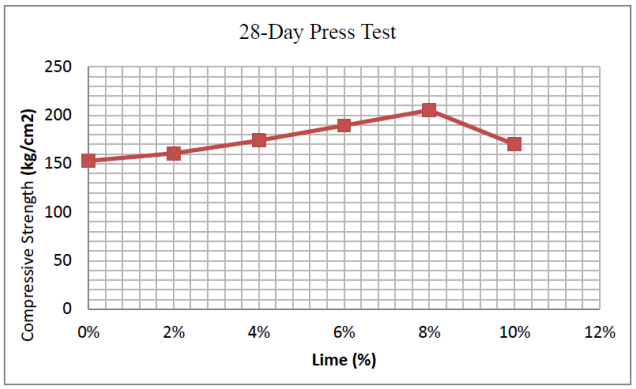

Figure 5. Relationship Between Compressive Strength and Lime Addition at 28 Days

The compressive strength of the paving block at 28 days has increased its compressive strength compared to the age of 21 days. The compressive strength increased until the addition of 8% lime, while the addition of 10% lime decreased by 17.2% compared to the compressive strength of 8% lime. The addition of 2% to 6% lime at the age of 28 days, the quality of the paving block is also still D quality, but the addition of 8% quality increases to class C.

3.2.5 Consolidation of Compressive Strength Test Results

Each test specimen is treated with soaking and then continued drying for testing. A comparison of the compressive strength test between normal paving blocks and paving blocks with the addition of chalk can be seen in Table 8.

Table 8. Summary of Compressive Strength Test Results

No.	Age (day)	NORMAL	KP 2%	KP 4%	KP 6%	KP 8%	KP 10%
1	0	0	0	0	0	0	0
2	7	92.84	105.91	117.68	124.22	132.06	120.29
3	14	120.29	125.52	129.45	138.60	143.83	138.60
4	21	138.60	147.75	154.29	163.44	171.29	150.37
5	28	152.98	160.83	173.90	189.59	205.28	169.98

At the age of 28, the addition of 2% lime resulted in an increase in compressive strength by 5% from normal. The addition of 4% lime resulted in an increase in compressive strength of 13% from normal. The addition of 6% lime resulted in an increase in compressive strength of 23% from normal. The addition of 8% lime resulted in an increase in compressive strength of 34% from normal.

The addition of 10% lime resulted in an 11% increase in compressive strength compared to its normal compressive strength.

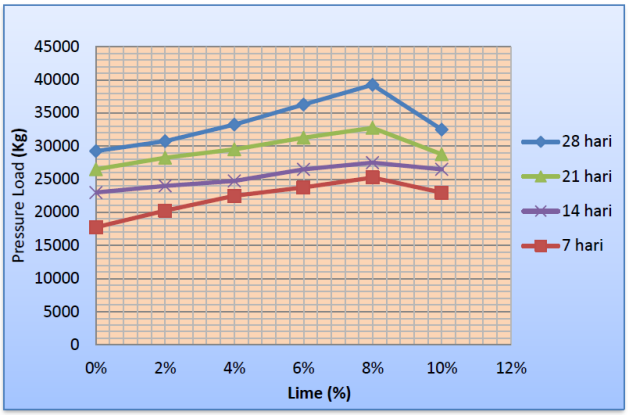

Figure 6. Comparison of Compressive Load with Lime Addition at 7, 14, 21, and 28 Days

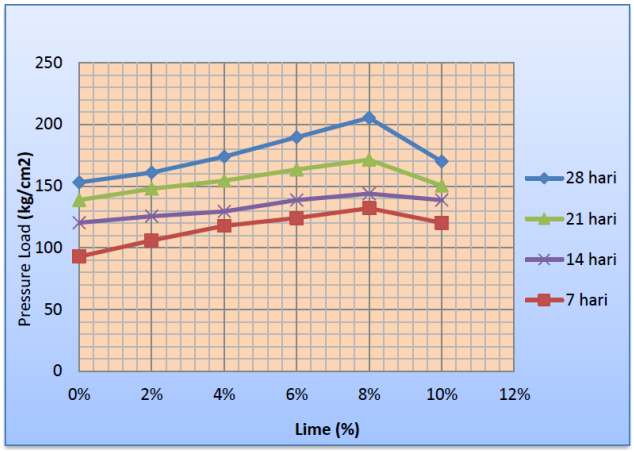

Figure 7. Comparison of Compressive Strength with Lime Addition at 7, 14, 21, and 28 Days

The results of the study obtained that the highest compressive strength occurred at the age of 28 days. The compressive strength of the paving block with the addition of lime of 2-6% at the age of 28 days is still classified as quality type D. After the addition of 8%, the quality of the paving block increases to class C quality. The maximum compressive strength occurs in the addition of 8% lime, which is 205 kg/cm2 (17 Mpa).

The addition of >8% lime resulted in a decrease in compressive strength. The addition of 10% lime at the age of 28 days experienced a reduction in compressive strength of 17% from the compressive strength of 8% of lime, so it is still classified as a class D quality paving block.

When compared to the results of the previous study, namely the use of fly ash (Endah S, 2009) that the normal compressive strength of paving blocks (1Pc: 4Ps) is 17.15 Mpa, the result is close to the compressive strength value with the addition of 8% lime, which is 17.0 Mpa. By adding lime and the use of PCC cement affects the compressive strength value.

In the study on the use of blanket soil (Nur Setiaji, 2013), the compressive strength of paving blocks using PC cement type I with a composition of 1Pc: 8Ps without the addition of other materials was obtained 12.19 Mpa. Meanwhile, in this study without the addition of lime (with composite cement), 12.68 Mpa was obtained. With the same

mixture composition, the compressive strength using composite cement (PCC) increased by 4% from the compressive strength with type I PC cement.

The results of the study comparing the quality of paving blocks produced manually with malas (Syukur Sebayang, 2011), where the difference in compressive strength between manual and masila is 8%.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that the addition of lime to the paving block mixture with a cement to sand ratio of 1:8 has a significant influence on the compressive strength value. Paving blocks without the addition of lime show a compressive strength of 152.98 kg/cm². The addition of lime with certain variations has been proven to be able to increase the compressive strength of paving blocks, especially at a percentage of 2% to 8%. This improvement was consistently observed at 7, 14, 21, and 28 days of age testing. However, the addition of lime of more than 8%, as in the 10% variation, actually causes a decrease in compressive strength. The lime percentage of 8% produced a maximum compressive strength value of 205 kg/cm² at the age of 28 days, which showed an improvement in quality from quality D to quality C according to the SNI 03-0691-1996 classification, so that the paving block was suitable for use in pedestrian areas. In contrast, the addition of 10% lime led to a 17% decrease in compressive strength compared to the 8% composition, indicating that excessive lime addition could negatively impact the strength of the paving block.

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