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Development of Paving Block Structure Variation for Traffic Safety and Comfort

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Abstract: Urban traffic congestion worldwide leads to air pollution, increased vehicle noise, and longer travel times for both private and public transit. Congestion adversely affects the well-being of road users and urban residents, and traffic accidents are closely linked to congestion. Traffic composition, road infrastructure, environmental conditions, vehicle design, and human behavior can cause congestion. Concrete block pavement is a practical option for improving traffic safety and increasing driving comfort at intersections with traffic lights. Concrete block paving roads are a cost-effective engineering solution for residential, commercial, municipal, and industrial environments. The study uses the Autocad program to create a simulation of a paved surface and a research tool to analyze the model of the research subject. Results indicate that pavement types subjected to higher loads exhibit more deformation than those under lower loads. Pavements with higher weights are more likely to deform, with the Herringbone 90° pavement type able to withstand a maximum load of 2100 kg and exhibiting the highest load deformation rate of 0.21 cm/kg. The study investigates the load-bearing abilities of different pavement kinds and patterns. The Basketweave pavement type has the lowest load capacity at 2077.9 kg and the lowest load deformation rate of 0.41 cm/kg.

Keywords: *Public Facilities; Road Infrastructure; Urban Traffic; Concrete Block Pavement*

1. Introduction

Traffic congestion in large urban areas around the world has been shown to have significant consequences, including increased levels of air pollution, increased vehicle noise, and longer trip durations for both private and public vehicles [1]. Congestion is a significant obstacle as it reduces the well-being of road users and urban residents. The occurrence of traffic accidents is strongly associated with traffic congestion, which in turn affects the sustainability of mobility in urban areas. This includes the significant social costs of traffic accidents and the implementation of public policies to reduce congestion, which is a fundamental aspect of contemporary cities [2]. The element of congestion is a significant variable that potentially impacts the likelihood of traffic accidents. Crashes can be caused by a variety of things, including the composition of traffic and road infrastructure, environmental conditions, vehicle design and specifications, and human factors [3]. The number of vehicles significantly affects traffic congestion, posing a considerable risk of traffic accidents [4].

Road infrastructure at traffic light stops significantly affects traffic safety and driving comfort. The use of concrete block pavements has emerged as a viable solution to address issues related to traffic safety and improve driving comfort at traffic light stop locations. According to Mascio et al., 2019), concrete block pavements are commonly used in constructing various infrastructures such as sidewalks, bike paths, residential street entrances, parking lots, industrial areas, ports, airports, and permeable areas. Concrete block paving has emerged as an technically attractive and cost-effective replacement for flexible and inflexible pavements [5]. The appeal of concrete block paving in various residential, commercial, municipal, and industrial environments, including parking areas, pedestrian crossings, traffic intersections, and roadways, can be attributed to its strength, durability, and surface aesthetics [6].

Concrete block paving has emerged as an attractive technique and a cost-effective substitute for flexible and rigid pavements. The appeal of concrete block paving in various residential, commercial, municipal, and industrial environments, including parking lots, pedestrian zones, traffic crossings, and roadways, can be attributed to its strength, durability, and surface aesthetics [6]. This particular form of pavement is valued as a rigid surface that has visual appeal, facilitates ease of use and pedestrian activity, exhibits high durability, requires minimal maintenance, and is environmentally friendly due to its ability to encourage water infiltration into the soil. To guarantee the longevity of concrete block paving in the country where it is to be installed, it is advisable to ensure that it meets the required class of resistance to atmospheric impacts [7].

Some paving block innovations [8] [9] [10] [11] [12] [5] [13] [14] [15] [16] [17], stating that paving block pavement at traffic light stops can effectively reduce traffic accidents and improve driving comfort. This article presents ideas for applying concrete block pavement under certain circumstances. For safety and convenience in traffic, it is possible to determine the appropriate pavement pattern structure, such as traffic lights, for paving blocks.

The use of paving blocks in traffic lights is a response to various problems that arose prior to their implementation. For example, the road may have uneven and deteriorating asphalt, resulting in damage at each traffic light zone. Designing a viable and durable road model for traffic light zones requires the application of innovative approaches.

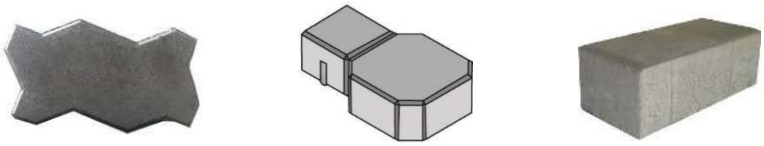
2. Methods

2.1. Autocad Analysis

Tests will be conducted using analytical and numerical methods. Autocad software applications produce simulations of real-world models in architectural planning and design. AutoCAD software is equipped with powerful application capabilities that allow users to apply various drawing materials and components, such as vegetation, trees, furniture, and people, to enhance the visual environment of two-dimensional drawings. This research uses the AutoCAD application to produce a pavement simulation and a research test tool to determine the model of the research subject.

2.2. Plaxis Analysis

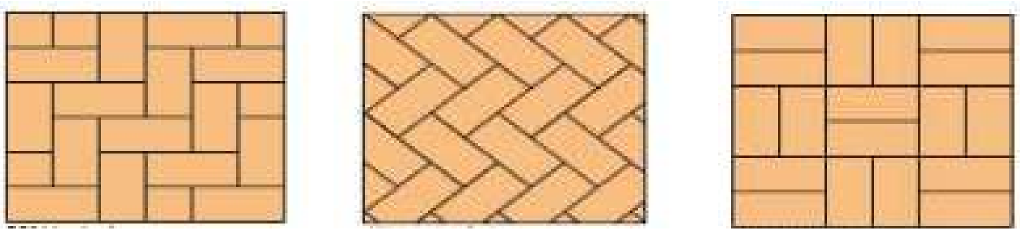
Utilizing AutoCAD and Plaxis software applications to facilitate the investigation. These software applications can facilitate the study by identifying moments and deformations manifested in simulated paving blocks and soil deflections due to deformation loads on different configurations such as bricks, trihex, and unpaved surfaces. The following are the categories of paving types used in this study:



(a) Paving Category A (b) Paving Category B (c) Paving Category C

Fig. 1. Paving Category

This study uses a pavement model that is organized as follows:



(a) Herringbone 90° (b) Herringbone 45° (c) Basketweave

Fig. 2. Paving Model

The tool to be used in this study is a horizontal shaft test device designed to assess the impact of braking force, vibration force, traction force, and centrifugal force in the following way:

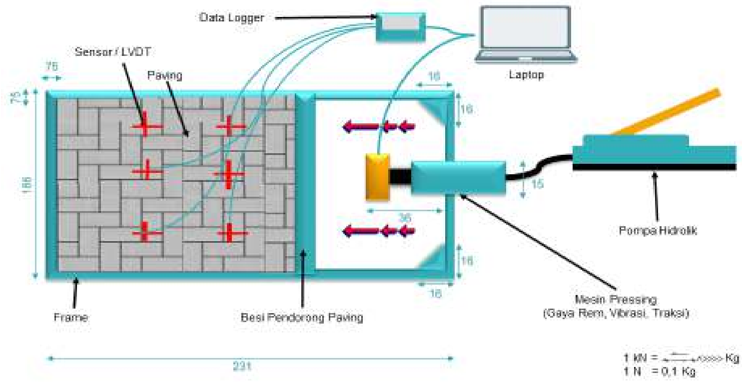


Fig. 3. Horizontal Test Equipment

This test equipment is used to determine the design of pavement layers which include subgrade layer (20 cm - 30 cm), top foundation layer (20 cm - 30 cm), sand layer (5 cm - 10 cm), and thick pavement layer (6 cm, 8 cm, and 10 cm) as shown below.

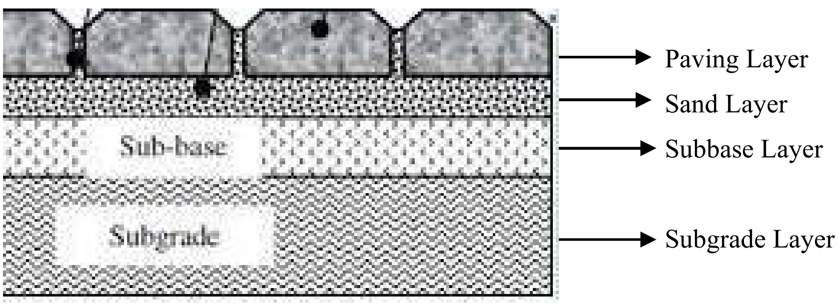


Fig. 4. Pavement Layers

The design of the device involved modifications to a jack to achieve optimal pressure levels, thereby increasing the compressive strength of the Pavement Block. The test device uses a manual hydraulic system that utilizes a data logger connected to a laptop to measure the pressure applied during the compressive test.

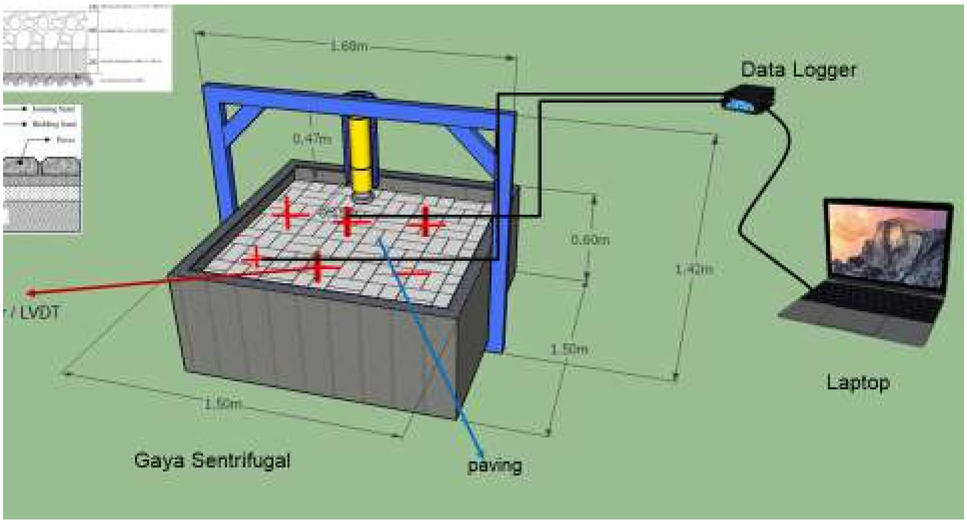


Fig. 5. Vertikal Test Equipment

3. Result and Discussion

The author conducted a grading test on several types and patterns, as shown in the following table.

Table 1. Pavement Type and Test Pattern

No	Paving Type	Test Patterns
1	HOLLAND 10 CM	Herringbone 90°
		Herringbone 45°
		Basketweave
2	UNIDECOR 10 CM	Herringbone 90°
		Herringbone 45°
		Basketweave
3	UNIPAVE 10 CM	Herringbone 90°
		Herringbone 45°
		Basketweave

Different pavement types were analyzed by testing different pavement patterns and thicknesses. The aim was to collect data describing the strength and durability of each pavement type using predetermined test patterns.

3.1. Holland 10cm Paving Type

In this type of Holland, the 10 cm thick pavement is arranged to form the following pattern models:

Fig. 6. Horizontal and Vertical Pavement Pattern Model Installation

a. Holland 10 cm Horizontal

The results of the 10 cm thick horizontal Holland pavement test yielded the following data:

Table 2. 10 cm Thick Horizontal Holland Pavement Test.

TYPE PAVING	TEST PATTERNS	HORIZONTAL PAVING TEST TABLE UNDER LOAD (2000KG to 2100 Kg)						
		LOAD (KG)	SHIFTING (CM)					
			LV3 40 CM	LV2 20 CM	LV1 10 CM	LV5 18 CM	LV6 21 CM	LV4 22 CM
HOLLAND 10 CM	Herringbone 90°	2076	0,22	0,15	0,19	0,1	0,2	0,38
	Herringbone 45°	2035	0,22	0,13	0,15	0,11	0,17	0,13
	Basketweave	2085,2	0,29	0,22	0,32	0,2	0,37	0,39

The horizontal test results above in the loading test (load 2000 kg to 2100 kg) in the 90° Herringbone test pattern at the heaviest shift point at a distance of LV4 = 22 cm with a load of 2076 kg. In the 45° Herringbone test pattern at the point of heaviest shift at a distance of LV3 = 40 cm with a load of 2035 kg. In the Basketweave test pattern at the point of heaviest shift at a distance of LV4 = 22 cm with a load of 2085.2 kg. The following is a visualization of the Horizontal testing graph of Holland paving with a thickness of 10 cm consisting of 3 (three) patterns (Herringbone 90, Herringbone 45, and Basketwave).

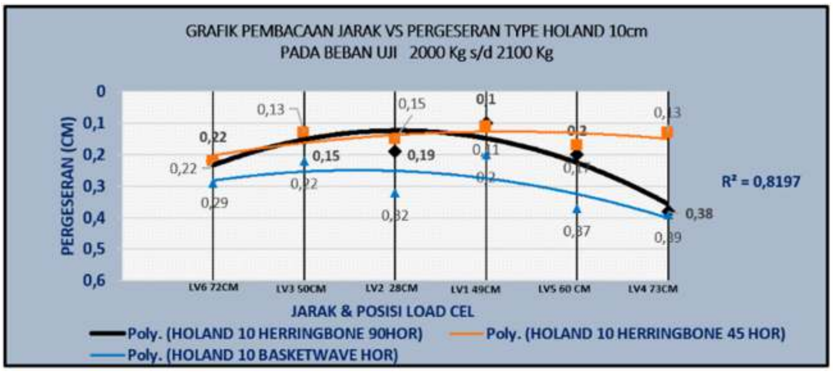


Fig. 7. Combined Road Motion Readings vs Type Holland 10cm Shift Horizontal Test All Patterns

Conclusion on the testing of Holland type paving with a thickness of 10 cm in a horizontal manner consisting of 3 pattern shapes (Heringbone 90, Heringbone 45 and Basketwave). From the test results of 3 pattern shapes, the best results are found in the herringbone 45 pattern with an LVD compressive value of 0.22 at LV3 40 cm.

b. Vertical 10 cm Hollad

The results of the 10 cm thick Vertical Holland pavement test yielded the following data in Table 3. Vertical test results above in the loading test (*load* 2000 kg to 2100 kg) in the 90 ° Herringbone test pattern at the heaviest shift point at a distance of LV4 = 22 cm with a load of 2098 kg. In the 45° Herringbone test pattern at the heaviest drop point at a distance of LV4 = 22 cm with a load of 2074 kg. In the Basketweave test pattern at the heaviest shift point at a distance of LV6 = 21 cm with a load of 2077.9 kg. The following is a visualization of the Vertical testing graph of Holland paving with a thickness of 10 cm consisting of 3 (three) patterns.

Table 3. 10 cm Thick Vertical Holland Pavement Test.

TYPE PAVING	TEST PATTERNS	VERTICAL PAVING TEST TABLE UNDER LOAD (2000KG to 2100 Kg)						
		LOAD (KG)	REDUCE (CM)					
			LV3 40 CM	LV2 20 CM	LV1 10 CM	LV5 18 CM	LV6 21 CM	LV4 22 CM
HOLLAND 10 CM	Herringbone 90°	2098	0,01	0,04	0,21	0,13	0,16	0,22
	Herringbone 45°	2074	0,02	0,07	0,14	0,12	0,13	0,15
	Basketweave	2077,9	0,02	0,03	0,17	0,17	0,18	0,1

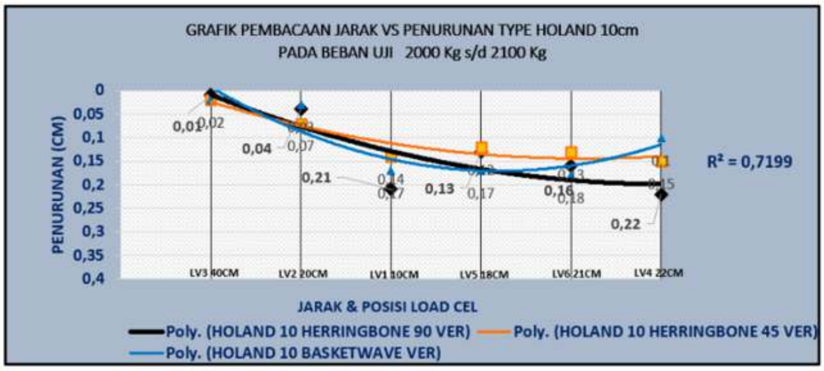


Fig. 8. Combined Road Motion Readings vs Type Holland 10cm Shift Horizontal Test All Patterns

Conclusion on the testing of Holland type paving with a thickness of 10 cm in a vertical way consisting of 3 forms of Pattern (Heringbone 90, Heringbone 45 and Basketwave). From the test results of 3 pattern shapes, the best results are found in the herringbone 45 pattern with a decrease value of 0.23 cm at LV.1 with a distance of 10 cm. from the load center.

3.2. Unidecor 10cm Paving Type

In this type of Unidecor, the 10 cm thick pavement is arranged to form the following pattern models:

Fig. 9. Horizontal and Vertical Pavement Pattern Model Installation

a. Unidecor 10 cm Horizontal

The results of the 10 cm thick horizontal Unidecor pavement test yielded the following data:

Table 4. 10 cm Thick Horizontal Unidecor Pavement Test.

TYPE PAVING	TEST PATTERNS	HORIZONTAL PAVING TEST TABLE UNDER LOAD (2000KG to 2100 Kg)						
		LOAD (KG)	REDUCE (CM)					
			LV3 40 CM	LV2 20 CM	LV1 10 CM	LV5 18 CM	LV6 21 CM	LV4 22 CM
UNIDECOR 10 CM	Herringbone 90°	2098,85	0,25	0,3	0,33	0,2	0,22	0,57
	Herringbone 45°	2081,2	0,32	0,26	0,2	0,1	0,37	0,44
	Basketweave	2099,2	0,57	0,38	0,61	0,25	0,64	0,68

Horizontal test results above in the loading test (load 2000 kg / D 2100 kg) in the 90 ° Herringbone test pattern at the heaviest shift point at a distance of LV4 = 22 cm with a load of 2098.85 kg. In the 45° Herringbone test pattern at the point of heaviest shift at a distance of LV4 = 22 cm with a load of 2081.2 kg. In the Basketweave test pattern at the point of heaviest shift at a distance of LV4 = 22 cm with a load of 2099.2 kg. The following is a visualization of the Unidecor Horizontal paving test graph with a thickness of 10 cm consisting of 3 (three) patterns. (Herringbone 90, Herringbone 45, and Basketwave)

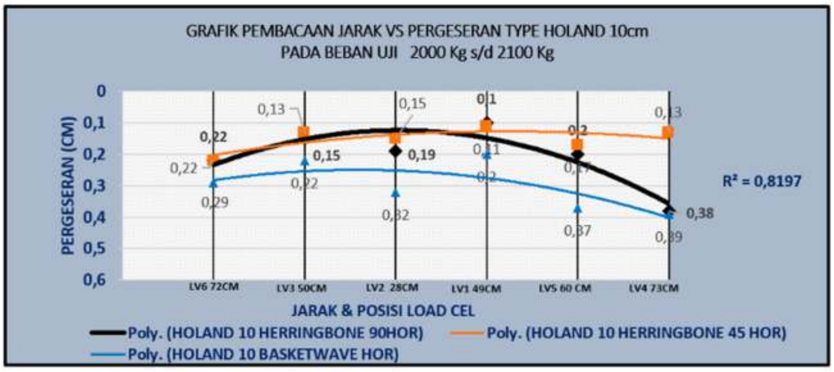


Fig. 10. Combined Road Motion Readings vs Type Unidecor 10cm Shift Horizontal Test All Patterns

Conclusion on the testing of Unidecor type paving with a thickness of 10 cm in a Horizontal manner consisting of 3 forms of Pattern (Heringbone 90, Heringbone 45 and Basketwave). From the test results of 3 pattern shapes, the best results are found in the herringbone 45 pattern with a shift value of 0.44 cm at LV4 which is 22 cm away from the load.

b. Vertical 10 cm Unidecor

The results of the 10 cm thick Vertical Unidecor pavement test yielded the following data in Table 5. Vertical test results above in the loading test (load 2000 kg / D 2100 kg) in the 90 ° Herringbone test pattern at the heaviest shift point at a distance of LV1 = 10 cm with a load of 2098.85 kg. In the 45° Herringbone test pattern at the point of heaviest shift at a distance of LV4 = 22 cm with a load of 2081.2 kg. In the Basketweave test pattern at the point of heaviest shift at a distance of

LV1 = 10 cm with a load of 2099.2 kg. The following is a visualization of the vertical testing graph of Unidecor paving with a thickness of 10 cm consisting of 3 (three) patterns.

Table 5. 10 cm Thick Vertical Unidecor Pavement Test.

TYPE PAVING	TEST PATTERNS	VERTICAL PAVING TEST TABLE UNDER LOAD (2000KG to 2100 Kg)						
		LOAD (KG)	REDUCE (CM)					
			LV3 40 CM	LV2 20 CM	LV1 10 CM	LV5 18 CM	LV6 21 CM	LV4 22 CM
UNIDECOR 10 CM	Herringbone 90°	2098,85	0,04	0,01	0,29	0,3	0,02	0,28
	Herringbone 45°	2081,2	0,02	0,02	0,12	0,2	0,1	0,18
	Basketweave	2099,2	0,01	0,015	0,28	0,09	0,01	0,17

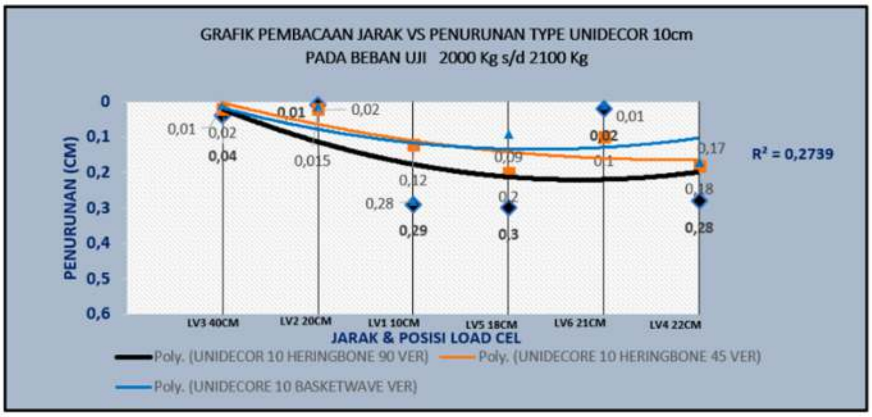


Fig. 8. Combined Road Motion Readings vs Type Holland 10cm Shift Horizontal Test All Patterns

Conclusion on the testing of Unidecor type paving with a thickness of 10 cm in a vertical manner consisting of 3 pattern shapes (Heringbone 90, Heringbone 45 and Basketwave). From the test results of 3 pattern shapes, the best results are found in the herringbone 45 pattern with an LVD compressive value of 0.18 at LV4 22 cm.

3.3. Unipave 10cm Paving Type

In this type of Unipave, the 10 cm thick pavement is arranged to form the following pattern models:

Fig. 12. Horizontal and Vertical Pavement Pattern Model Installation

a. Unipave 10 cm Horizontal

The results of the 10 cm thick horizontal Unipave pavement test yielded the following data:

Table 6. 10 cm Thick Horizontal Unipave Pavement Test.

TYPE PAVING	TEST PATTERNS	HORIZONTAL PAVING TEST TABLE UNDER LOAD (2000 KG to 2100 KG)						
		LOAD (KG)	REDUCE (CM)					
			LV3 40 CM	LV2 20 CM	LV1 10 CM	LV5 18 CM	LV6 21 CM	LV4 22 CM
UNIPAVE 10 CM	Herringbone 90°	2083,2	0,28	0,3	0,25	0,21	0,26	0,53
	Herringbone 45°	2.099,34	0,26	0,24	0,24	0,06	0,51	0,4
	Basketweave	2081,1	0,29	0,27	0,3	0,24	0,37	0,48

The horizontal test results above in the loading test (load 2000 kg to 2100 kg) in the 90° Herringbone test pattern at the heaviest shift point at a distance of LV4 = 22 cm with a load of 2083.2 kg. In the 45° Herringbone test pattern at the point of heaviest shift at a distance of LV6 = 21 cm with a load of 2099.3 kg. In the Basketweave test pattern at the point of heaviest shift at a distance of LV4 = 22 cm with a load of 2081.1 kg. The following is a visualization of the Unipave Horizontal paving test graph with a thickness of 10 cm consisting of 3 (three) patterns.

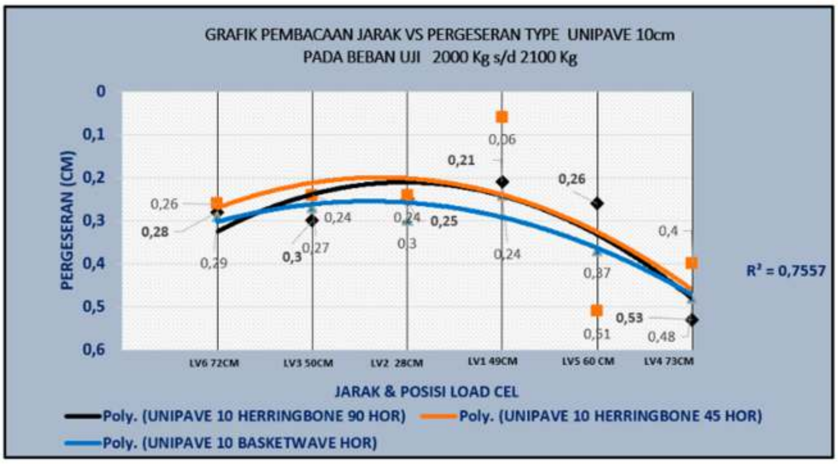


Fig. 13. Combined Road Motion Readings vs Type Unipave 10cm Shift Horizontal Test All Patterns

Conclusion on the testing of Unipave type paving with a thickness of 10 cm in a Horizontal manner consisting of 3 forms of Pattern (Heringbone 90, Heringbone 45 and Basketwave). From the test results of 3 pattern shapes, the best results are found in the herringbone 45 pattern with a shift value of 0.51 cm at LV6 which is 21 cm from the load center.

b. Vertical 10 cm Unipave

The results of the 10 cm thick Vertical Unipave pavement test yielded the following data in Table 7. The vertical test results above in the loading test (load 2000 kg to 2100 kg) in the 90° Herringbone test pattern at the heaviest drop point at a distance of LV1 = 10 cm with a load of 2081.1 kg. In the 45° Herringbone test pattern at the heaviest drop point at a distance of LV1 = 10 cm with a load of 2083.2 kg. In the Basketweave test pattern, the heaviest drop point is at a distance of LV1 = 10 cm with a load of 2099.337 kg. The following is a visualization of the vertical testing graph of Unidecor paving with a thickness of 10 cm consisting of 3 (three) patterns.

Table 7. 10 cm Thick Vertical Unipave Pavement Test.

TYPE PAVING	TEST PATTERNS	VERTICAL PAVING TEST TABLE UNDER LOAD (2000 KG to 2100 KG)						
		LOAD (KG)	REDUCE (CM)					
			LV3 40 CM	LV2 20 CM	LV1 10 CM	LV5 18 CM	LV6 21 CM	LV4 22 CM
UNIPAVE 10 CM	Herringbone 90°	2083,2	0,03	0,02	0,17	0,11	0,02	0,13
	Herringbone 45°	2.099,34	0,06	0,02	0,25	0,03	0,01	0,13
	Basketweave	2081,1	0,06	0,08	0,27	0,27	0,16	0,26

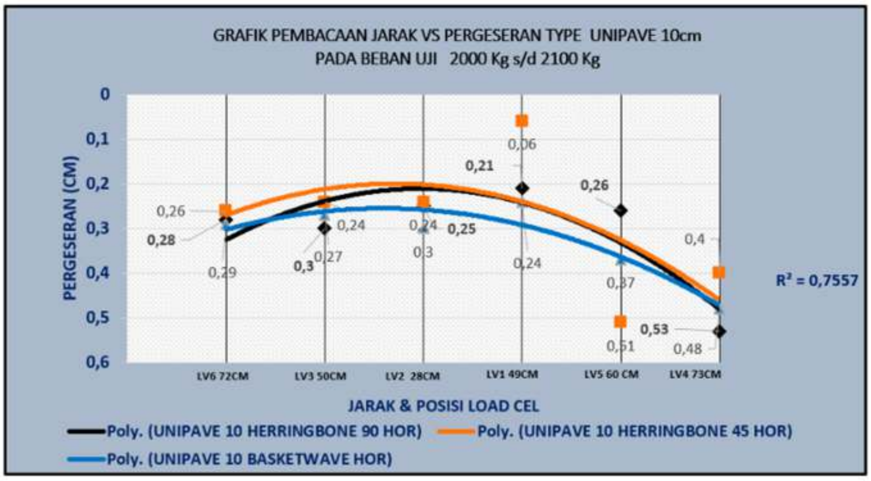


Fig. 14. Combined Road Motion Readings vs Type Unipave 10cm Shift Horizontal Test All Patterns

Conclusion on the testing of Unipave type paving with a thickness of 10 cm in a vertical manner consisting of 3 pattern shapes (Heringbone 90, Heringbone 45 and Basketwave). From the test results of 3 pattern shapes, the best results are found in the herringbone 90 pattern with a LVD reduction value of 0.17 at LV1 10 cm.

4. Conclusions

Based on the results of tests that have been carried out on Holland paving with a thickness of 10 cm, various patterns have been tested to determine their durability and effectiveness. This test used the horizontal method with loads ranging from 2000 kg to 2100 kg. The three patterns tested include Herringbone 90°, Herringbone 45°, and Basketweave.

The test results show that the Herringbone 90° pattern has the heaviest shifting point at a distance of LV4 = 22 cm with a load of 2076 kg. The 45° Herringbone pattern showed the best performance with the heaviest shifting point at LV3 distance = 40 cm with a load of 2035 kg and an LVD compressive value of 0.22. Meanwhile, the Basketweave pattern had the heaviest displacement point at LV4 = 22 cm with a load of 2085.2 kg.

The resulting test graph provides a clear visualization of the horizontal performance of 10 cm thick Holland paving in the various patterns. Of the three patterns tested, the 45° Herringbone pattern proved to be the most effective in load-bearing, followed by the Basketweave and 90° Herringbone patterns. This shows that the design of the paving pattern can affect the material's ability to withstand heavy loads.

Thus, it can be concluded that in the application of Holland paving with a thickness of 10 cm, proper pattern selection is critical to ensure optimal durability and performance. The 45° Herringbone pattern is the best choice based on these test results, providing a good balance between load distribution and resistance to shifting.

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