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Influence of Paving Block Geometry on Physical and Mechanical Properties

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ABSTRACT: The geometry of paving blocks plays a crucial role in determining their physical and mechanical performance in pavement systems, particularly under identical material and production conditions. While previous studies have predominantly focused on material composition, the influence of geometric configuration on paving block performance remains relatively underexplored. Therefore, this study investigates the effect of paving block geometry truepave, octagon, and hexagon on the physical and mechanical characteristics of concrete paving blocks produced with a mix proportion of 1 : 2.5 : 0.5 (cement : sand : ½-inch crushed stone).

All specimens were manufactured using identical materials, water–cement ratio, compaction method, and curing conditions to isolate the influence of geometry. Physical properties evaluated included density, water absorption, and resistance, while mechanical performance was assessed through compressive strength testing at the designated curing age in accordance with relevant standards.

The results indicate that paving block geometry significantly affects both physical and mechanical characteristics. Octagon-shaped paving blocks exhibited the highest density and compressive strength, indicating superior compaction efficiency and more effective stress distribution. Hexagon-shaped blocks demonstrated balanced physical and mechanical performance, satisfying structural pavement requirements. In contrast, truepave blocks showed lower density and compressive strength, despite exhibiting lower water absorption, suggesting that permeability alone does not govern mechanical performance.

Overall, the findings confirm that geometric configuration is a critical design parameter in optimizing paving block performance. The novelty of this study lies in its systematic evaluation of geometry as an independent factor for performance optimization without altering mix design.

KEYWORDS: Paving block shape; truepave, octagon, and hexagon paving blocks; Water absorption; resistance ; compressive strength.

I. INTRODUCTION

Concrete paving blocks are widely used in urban infrastructure applications such as pedestrian walkways, parking areas, residential roads, and public open spaces due to their modular construction system, ease of installation, and maintenance flexibility. Compared to conventional rigid pavements, paving blocks offer advantages in terms of repairability, surface aesthetics, and adaptability to local loading and environmental conditions (Knapton, 1996; Shackel, 2000).

Recent developments in pavement engineering emphasize the importance of optimizing not only material composition but also geometric configuration to enhance pavement performance and service life. The geometry of paving blocks influences stress distribution, interlocking behavior, compaction efficiency, and load transfer mechanisms within the pavement system (Shackel, 2008). As a result, paving block shape has become an important design parameter alongside material strength and thickness.

Previous studies have primarily focused on the mechanical performance of paving blocks in terms of compressive strength, flexural strength, and abrasion resistance, often emphasizing material proportioning and curing conditions (Neville, 2011; Mindess et al., 2003). Several researchers have reported that higher density and lower Resistance generally lead to improved mechanical strength and durability of concrete paving blocks (Mehta & Monteiro, 2014). However, these studies commonly adopt a single or limited paving block geometry, typically truepave, without comprehensive comparison among different shapes.

More recent investigations have explored interlocking paving block systems, highlighting the role of shape in enhancing pavement stability and resistance to traffic loads (Huang et al., 2016; Shackel & Pearson, 2014). While these studies demonstrate the structural benefits of interlocking mechanisms, the relationship between paving block geometry and fundamental physical properties such as water absorption and resistance remains

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insufficiently addressed. Furthermore, comparative experimental data evaluating multiple geometric shapes under identical material composition and production conditions are still limited.

This lack of integrated evaluation represents a clear research gap, particularly for studies that simultaneously assess physical and mechanical characteristics while isolating the effect of geometry. In practical applications, paving blocks with different shapes are often produced using similar mix proportions, yet their performance variations due to geometric differences are not fully understood. This gap becomes more critical in developing countries, where standardized mix designs are commonly applied to various paving block shapes without sufficient performance validation.

Therefore, this study aims to experimentally investigate the influence of paving block geometry specifically truepave, octagon, and hexagon shapes on the physical and mechanical characteristics of concrete paving blocks. All specimens were produced using an identical mix proportion of 1: 2.5: 0.5 (cement : sand : ½-inch crushed stone) to ensure that observed performance differences are attributed primarily to geometric configuration. The findings of this research are expected to contribute to a better understanding of geometry-driven performance optimization and to support more rational paving block design and selection for.

Paving block geometry truepave, octagon, and hexagon

truepave octagon hexagon

II. RESEARCH METHODOLOGY

This study employed an experimental research design to evaluate the influence of paving block geometry on the physical and mechanical characteristics of concrete paving blocks. Three different geometric configurations ruepave, octagon, and hexagon were investigated under identical material composition, manufacturing procedures, and curing conditions. The methodology was structured to ensure that observed performance differences were primarily attributed to geometric effects.

2.1 Materials and Equipment

The primary materials used in this study consisted of ordinary Portland cement, natural river sand as fine aggregate, and crushed stone with a nominal maximum size of ½ inch as coarse aggregate. The paving blocks were produced using a fixed mix proportion of 1 : 2.5 : 0.5 (cement : sand : crushed stone) by weight. Clean potable water was used for mixing and curing in accordance with standard concrete practice (Neville, 2011).

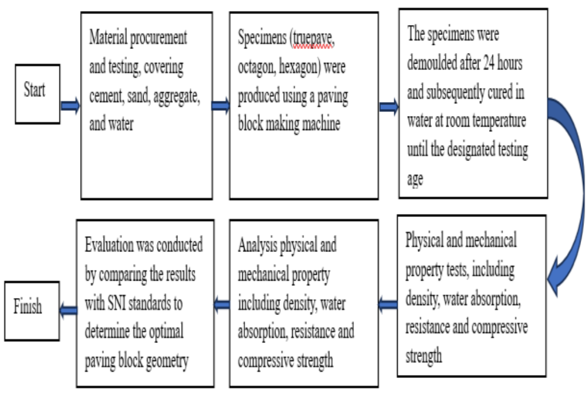
Prior to specimen preparation, fine and coarse aggregates were characterized to ensure compliance with relevant standards, including particle size distribution and cleanliness. All materials were stored in a dry condition to minimize variability during the mixing process.

The main equipment utilized in this study included steel molds for truepave, octagon, and hexagon paving blocks, a mechanical concrete mixer, a vibrating and compaction in paving block machine, and curing by water sprinkling/curing by watering. Testing equipment comprised a digital weighing balance, a water absorption test setup, and a compression testing machine for mechanical performance evaluation. All testing instruments were calibrated to ensure measurement accuracy (ASTM C140, 2022).

2.2 Research Procedure

The research procedure was conducted through several sequential stages, as illustrated in the overall experimental workflow.

Research Flowchart



First, material procurement and testing were conducted, covering cement, sand, aggregate, and water, to ensure compliance with the required specifications. All raw materials were then weighed according to the predetermined mix proportions. The dry materials were mixed until a homogeneous blend was achieved, followed by the gradual addition of water to obtain a workable yet stiff concrete mixture suitable for paving block production.

Specimens with different geometrical shapes, namely truepave, octagon, and hexagon, were produced using a paving block making machine. The fresh concrete mixture was placed into the corresponding moulds and compacted mechanically to reduce entrapped air and improve density.

After casting, the specimens were demoulded after 24 hours and subsequently cured in water at room temperature until the designated testing age. Water curing was applied to ensure proper cement hydration and to minimize early-age cracking (Mehta & Monteiro, 2014).

Physical and mechanical property tests were then conducted, including density, water absorption, resistance , and compressive strength. The compressive strength test was performed using a universal testing machine at the specified curing age. All tests were carried out on multiple specimens for each paving block geometry to ensure data reliability and repeatability (Shackel, 2008).

Finally, the test results were evaluated by comparison with Indonesian National Standards (SNI) to determine the optimal paving block shape based on physical and mechanical performance.

2.3 Data Analysis Method

The experimental data were analyzed using descriptive and comparative statistical methods. Average values, standard deviations, and coefficients of variation were calculated for each physical and mechanical parameter to assess consistency and variability among specimens. Comparative analysis was performed to evaluate differences in performance between truepave, octagon, and hexagon paving blocks.

The influence of geometry on physical and mechanical characteristics was assessed by comparing test results under identical mix proportions and curing conditions. Observed trends were interpreted based on differences in stress distribution, compaction efficiency, and geometric configuration. Where applicable, the results were compared with relevant standard requirements to evaluate compliance and practical applicability (Shackel & Pearson, 2014).

The findings were further discussed in relation to existing literature to identify similarities, deviations, and potential explanations for geometry-driven performance variations. This analytical approach provides a systematic basis for assessing the role of paving block geometry in pavement material performance.

III. RESULTS AND DISCUSSION

This section presents the experimental results obtained from physical and mechanical testing of concrete paving blocks with different geometric shapes, followed by a detailed discussion linking the findings to theoretical considerations and previous studies.

3.1 Results

The experimental results demonstrate that paving block geometry has a noticeable influence on both physical and mechanical characteristics. The measured physical properties included density, water absorption, and resistance, while the mechanical performance was evaluated based on compressive strength.

Table presents the average values of density, water absorption, and resistance for truepave, octagon, and hexagon paving blocks. The truepave paving blocks exhibited the highest density and the lowest water absorption, indicating a more compact internal structure. In contrast, octagon -shaped paving blocks showed relatively higher water absorption and resistance, suggesting less efficient compaction. Hexagon paving blocks demonstrated intermediate behavior between the two geometries.

Physical properties of paving blocks values of density, water absorption, and resistance for truepave, octagon, and hexagon paving blocks

Geometry	Density	Absorption (%)	Resistance (mm/s)
Truepave	1,855.26	7.326	0.420
Hexagon	1,959.85	9.598	0.355
Octagon	2,019.47	8.755	0.360

Based on table the octagon-shaped paving blocks exhibited the highest density, reaching 2,019.47 kg/m³, followed by the hexagon and true pave shapes. A higher density indicates a more compact internal structure, which is generally associated with improved mechanical performance and durability. Therefore, from the density perspective, the octagon geometry demonstrates the most favorable performance.

In terms of water absorption, the true pave shape showed the lowest absorption value at 7.326%, indicating better resistance to water ingress and a denser pore structure compared to the other geometries. The hexagon shape recorded the highest absorption, while the octagon showed an intermediate value. Lower water absorption is desirable as it reflects enhanced durability and reduced susceptibility to moisture-related deterioration.

Regarding resistance, the hexagon-shaped paving blocks exhibited the lowest resistance value

(0.355 mm/s), followed closely by the octagon shape, whereas the true pave shape showed the highest value. Since lower resistance values indicate better performance under the applied testing conditions, the hexagon geometry performs best in terms of resistance, with the octagon shape also demonstrating competitive behavior.

Overall, each paving block geometry shows distinct performance advantages depending on the evaluated parameter. The octagon shape provides the best performance in terms of density, the true pave shape excels in minimizing water absorption, and the hexagon shape offers the lowest resistance value. Considering the combined physical performance criteria, the octagon-shaped paving block presents the most balanced and favorable overall performance, particularly due to its superior density and acceptable absorption and resistance values.

The compressive strength results for each paving block geometry are summarized in Table 2. The truepave specimens achieved the highest compressive strength, followed by the hexagon specimens, while the octagon-shaped specimens recorded the lowest values. This trend indicates that geometric configuration plays a significant role in determining load-bearing capacity.

Mechanical properties of paving blocks with different geometries

Geometry	Compressive strength (MPa)	Qualified base on SNI 03-0691-1996
Truepave	14.739-17.234	C - B
Hexagon	18.331- 21.124	B
Octagon	25.589 - 27.982	B

Table presents the compressive strength performance of paving blocks with different geometrical shapes and their corresponding qualification based on SNI 03-0691-1996. The results indicate that paving block geometry has a significant influence on compressive strength.

The true pave geometry exhibited compressive strength values ranging from 14.739 to 17.234 MPa, which fall within the C–B classification according to SNI. This indicates that although the true pave shape satisfies the minimum requirements for paving blocks, its strength performance is relatively lower compared to the other geometries.

The hexagon-shaped paving blocks demonstrated higher compressive strength values, ranging from 18.331 to 21.124 MPa, qualifying them under Class B. This improvement suggests that the hexagonal geometry provides better load distribution and interlocking efficiency, resulting in enhanced compressive performance.

The octagon geometry achieved the highest compressive strength, with values ranging from 25.589 to 27.982 MPa, and also met the Class B requirement. The significantly higher strength indicates that the octagonal shape offers superior stress distribution and structural stability under compressive loading.

Overall, based on compressive strength evaluation and compliance with SNI 03-0691-1996, the octagon-shaped paving block exhibits the best mechanical performance, followed by the hexagon shape, while the true pave geometry shows the lowest strength classification. These results confirm that paving block geometry plays a crucial role in determining mechanical performance and suitability for structural applications.

3.2 Discussion

The observed differences in physical and mechanical properties among the paving blocks can be primarily attributed to the influence of geometric configuration on compaction efficiency, internal density, and stress distribution. Although all specimens were produced using identical mix proportions and curing conditions, variations in geometry resulted in distinct performance characteristics.

Based on the results presented in Table 1, the octagon-shaped paving blocks exhibited the highest density, indicating a more compact internal structure. Higher density is generally associated with improved particle packing and reduced internal voids, which contributes positively to mechanical performance. This observation is consistent with the compressive strength results in Table 2, where the octagon geometry achieved the highest compressive strength values (25.589–27.982 MPa) and satisfied the Class B requirement of SNI 03-0691-1996. The superior performance of the octagon shape can be attributed to its ability to distribute compaction energy and applied loads more evenly, thereby enhancing structural stability under compressive loading (Shackel, 2008).

The hexagon-shaped paving blocks demonstrated balanced physical and mechanical performance. As shown in Table 1, the hexagon specimens exhibited moderate density, relatively low resistance values, and acceptable water absorption. In terms of mechanical behavior, the hexagon geometry achieved compressive strength values ranging from 18.331 to 21.124 MPa, qualifying it under Class B according to SNI (Table 2). The polygonal geometry of the hexagon is known to improve load transfer efficiency and reduce stress concentration within segmental pavement systems, which contributes to its stable performance (Shackel & Pearson, 2014).

In contrast, the true pave geometry exhibited the lowest density and lowest compressive strength, with strength values ranging from 14.739 to 17.234 MPa, falling within the C–B classification based on SNI (Table 2). However, as indicated in Table 1, true pave specimens showed the lowest water absorption, suggesting a relatively less permeable pore structure. Despite this advantage, the lower density and compressive strength imply that the simple geometry may not have allowed optimal compaction efficiency during casting, resulting in reduced load-bearing capacity under compression.

The relationship between resistance and compressive strength observed in this study aligns with established concrete theory, which states that higher resistance values are often associated with increased void content and weaker internal bonding, leading to reduced mechanical strength (Neville, 2011; Mehta & Monteiro, 2014). This relationship is evident when comparing the true pave geometry, which exhibited higher resistance and lower compressive strength, with the octagon and hexagon shapes that showed lower resistance values and superior mechanical performance.

Overall, the results confirm that paving block geometry is a critical design parameter influencing both physical and mechanical properties. Even with identical material composition and curing conditions, geometric variation alone significantly affects density, water absorption, resistance, and compressive strength. Therefore, selecting an appropriate paving block geometry—particularly the octagon shape, which demonstrated the most favorable overall performance—offers a practical approach to enhancing pavement durability and structural performance without modifying the mix design (Knapton, 1996).

IV. CONCLUSIONS

This study investigated the effect of paving block geometry—truepave, octagon, and hexagon—on the physical and mechanical characteristics of concrete paving blocks produced using an identical mix proportion of 1 : 2.5 : 0.5 (cement : sand : ½-inch crushed stone). Based on the experimental results, the following conclusions can be drawn:

1. Paving block geometry has a significant influence on both physical and mechanical properties, including density, water absorption, resistance, and compressive strength, even when identical materials, mix proportions, and curing conditions are applied.
2. Octagon-shaped paving blocks exhibited the highest density and compressive strength, indicating superior compaction efficiency and more effective stress distribution under compressive loading. These characteristics enabled the octagon geometry to achieve the most favorable mechanical performance and meet the Class B requirement of SNI 03-0691-1996.
3. Hexagon paving blocks demonstrated balanced physical and mechanical performance, characterized by moderate density, relatively low resistance values, and compressive strength that also satisfied Class B requirements. This suggests that the hexagonal geometry provides effective load transfer and structural stability for pavement applications.
4. Truepave paving blocks showed the lowest compressive strength and density, despite exhibiting the lowest water absorption. This indicates that lower permeability alone does not necessarily translate into higher mechanical performance, particularly when compaction efficiency and internal density are limited by geometric configuration.

Overall, the findings confirm that geometric configuration is a critical design parameter in optimizing the performance of concrete paving blocks. Among the evaluated geometries, the octagon shape offers the most favorable overall performance, followed by the hexagon geometry, making them more suitable for applications requiring higher mechanical strength and structural reliability.

Future research is recommended to investigate the combined effects of paving block geometry and interlocking behaviour under repeated or dynamic loading conditions. Furthermore, numerical modelling and long-term durability assessments are suggested to provide deeper insight into geometry-driven performance optimization for pavement systems.

SOME OF THE ADVANAGES FROM THE RESULTS ABOVE

1. Geometry-Driven Performance Improvement
The results confirm that paving block geometry alone—without changing mix proportion, materials, or curing conditions—can significantly enhance physical and mechanical performance. This highlights geometry as an effective and practical design parameter.
2. Superior Mechanical Performance of Octagon Geometry
Octagon-shaped paving blocks exhibited the highest density and compressive strength (25.589–27.982 MPa), indicating better

compaction efficiency and more uniform stress distribution. This makes the octagon geometry advantageous for structural pavement applications requiring higher load-bearing capacity.

3. Balanced Performance of Hexagon Geometry
Hexagon paving blocks demonstrated balanced physical and mechanical characteristics, including moderate density, low resistance values, and compressive strength meeting Class B requirements. This balance supports their suitability for pavements requiring stable load transfer and durability.
4. Reduced Water Absorption in Truepave Geometry
Truepave paving blocks showed the lowest water absorption, indicating better resistance to water ingress. This provides an advantage in environments where moisture control and durability against water-related deterioration are critical.
5. Compliance with National Standards (SNI**)**
Both octagon and hexagon paving blocks met the Class B requirements of SNI 03-0691-1996, confirming their practical applicability for pavement construction under Indonesian standards.

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