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COMPRESSIVE STRENGTH OF NO - FINES CONCRETE INTERLOCKING PAVING BLOCKS

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Abstract – No-fines concrete, a permeable mix of coarse aggregate, cement, and water, excludes sand to facilitate drainage, making it suitable for low-traffic pavements where storm water runoff is a concern. Some researchers have modified it with minor sand or admixtures, enhancing strength and durability, leading to the term "porous" or "pervious" concrete. This study investigates no-fines concrete's potential for interlocking paving blocks, focusing on its density, compressive strength, and tensile strength. Using aggregate-to-cement ratios of 4:1, 6:1, and 8:1, with coarse aggregates (9.5-19 mm) and Ordinary Portland cement and water-to-cement ratios of 0.40, 0.42, and 0.45, samples were cast, demolded after 24 hours, and cured by immersion for 7, 14, and 28 days. Findings revealed that as the aggregate-to-cement ratio decreased, the compressive strength, tensile strength, and density of the no-fines concrete increased, with the 4:1 ratio at a 0.40 water-to-cement ratio achieving the highest compressive strength of 8.24 MPa. However, prolonged curing in water led to a reduction in strength, indicating that continuous immersion is unsuitable for no-fines concrete. Density values ranged from 1778 to 2155 kg/m³, lower than conventional concrete. The study recommends a 2:1 aggregate-to-cement ratio to further enhance strength without sacrificing permeability. Additionally, selecting an appropriate curing method is essential for optimal performance. This mix is well-suited for low-load applications like footpaths, parking areas, and recreational courts.

Keywords: No-fines concrete, pervious concrete, Compressive strength, Interlocking paving blocks, Concrete durability.

1. Introduction

No-fines concrete is a unique construction material composed solely of coarse aggregates, cement paste and water, devoid of fine aggregates. According to Marshdi et al. (2021), it is characterized by coarse aggregate particles each encased in a layer of cement paste approximately 1.3 mm thick. For optimal performance, the coarse aggregate used should be single-sized, specifically ranging from 20 mm to 10 mm, to facilitate the formation of substantial pore spaces as the aggregates interlock with one another, allowing for enhanced structural integrity. Surahyo et al. (2019) emphasizes that the use of single-sized coarse aggregates is critical in achieving effective no-fines concrete, which not only provides a lightweight alternative due to its large voids but also offers an aesthetically appealing appearance.

No-fines concrete is recognized by various names, including zero fines concrete, pervious concrete, and porous concrete. Its key feature is the ability to permit water to permeate through the material, thereby mitigating environmental issues associated with conventional asphalt and concrete pavements. It is particularly advantageous in low-traffic areas such as parking lots, residential roads, driveways, and footpaths (Xie et al., 2019). In urban settings, where extensive areas are covered with traditional cement concrete, rainwater runoff poses significant challenges by limiting the natural percolation into the soil, ultimately affecting groundwater levels (Sangsefidi et al., 2019). In contrast, no-fines concrete presents numerous benefits over conventional concrete, including lower density, increased permeability, reduced capillary action, lower thermal conductivity, and minimal drying shrinkage. Given its large voids, this material allows for effective moisture drainage into the soil, making it a promising alternative to traditional concrete in low-traffic applications.

Historically, no-fines concrete originated in Europe during the 19th century and was initially applied in various contexts, such as load-bearing walls and prefabricated panels. In the UK, two houses were constructed in 1852 utilizing gravel and no-fines concrete, primarily motivated by cost efficiency due to the reduced cement content. Its resurgence as a viable construction material began in 1923, especially in regions such as Scotland, Liverpool, London, and Manchester. The post-World War II era saw a steady increase in its usage across Europe, with applications extending to Venezuela, West Africa, Australia, Russia, and the Middle East, primarily due to its advantageous permeability characteristics. In the United States, no-fines concrete was first implemented in Florida, Utah, and New Mexico, and has since spread to states like California, Illinois, Oklahoma, and Wisconsin, where it has become a multifaceted tool in construction (Eathakoti et al., 2015).

Recently, no-fines concrete has found applications as a load-bearing material in high-rise buildings, with notable examples including a building in Stuttgart, Germany, which utilized conventional concrete for its lower six stories and no-fines concrete for the upper thirteen. Conventional interlocking concrete paving blocks, widely used for pavements, parking lots, and footpaths, often contain fine aggregates, limiting water percolation and contributing to flooding during heavy rainfall. Thus, the exploration of no-fines interlocking paving blocks presents an opportunity to address this issue while potentially reducing production costs due to the lower cement content of no-fines concrete.

Environmental degradation caused by flooding and erosion, linked to the inadequate drainage of conventional concrete, underscores the need for effective alternatives that promote rainwater infiltration. Moreover, the rising cost of cement, particularly in developing countries, poses a significant challenge for low-income earners seeking affordable housing (King et al., 2017). By leveraging the properties of no-fines concrete, which features large voids that enhance its permeability and reduce the overall cement requirement, this study aims to assess the suitability of no-fines concrete interlocking paving blocks, particularly in damp or marshy areas. Specifically, it will examine the density of no-fines concrete interlocking paving blocks at varying aggregate-to-cement ratios, evaluate the impact of mix proportions on their compressive strength, and test the tensile strength of no-fines concrete across different mixing ratios.

2.0 The No-fines concretes Applications

No-fines concrete (NFC) has found diverse applications within civil engineering, capitalizing on its unique properties and advantages. Despite its remarkable thermal insulation properties, NFC is primarily composed of cement and coarse aggregates, excluding fine aggregates. This composition allows NFC to be engineered with controlled voids, enhancing its thermal insulation capacity. In construction, non-pavement applications of NFC include its use in housing structures, tennis courts, drainage systems, and drainage tiles (Marshdi et al., 2021). As a pavement material, NFC has been utilized in pavement edge drainage systems, low-volume road surfaces, and extensive parking areas. Over time, NFC pavements may experience raveling, typically around ten years' post-construction. However, pore pressure issues can be mitigated by using NFC in stiff pavement designs, where it can additionally function as a stormwater management system. Compared to conventional concrete, NFC often results in cost savings, with an estimated service life of 20–40 years (Onuaguluchi & Banthia, 2024).

A distinctive benefit of NFC is its light color, which contributes to reducing ground-level ozone formation. To prevent capillary action from allowing rainwater infiltration, the voids in NFC should be optimized. Consequently, rain on exterior NFC walls will move minimally horizontally before reaching the base, ensuring no fines are introduced. This makes NFC particularly suitable for exterior walls in buildings (Newman & Choo, 2003).

Permeable concrete, a type of NFC, permits water to pass through its structure, allowing heavy rainfall to be absorbed and directed through a layer of gravel and tubing designed for storm water management. This property reduces storm water runoff, mitigating flood risks and reducing the demand for rainwater treatment facilities, thereby enhancing the efficiency of surface water discharge and supporting groundwater replenishment. The porous gravel layer in permeable NFC typically features 15-30% void space, facilitating water flow (Thomas et al., 2020). Compact NFC structures may incorporate large, granulated grains, either with or without fine particles, to maintain water permeability. A concrete mix is sometimes used to bind these particles while allowing water to penetrate, which aids in managing flood and heavy rainfall scenarios.

3.0 Materials and Methods:

3.1.1*Cement*: cement as a material with adhesive and cohesive properties which make it capable of binding mineral fragments into a compact whole. Cement is a binder in the concrete mixture. Ordinary Portland cement was used to bind a singed size aggregate of no-fines concrete together.

3.1.2 *Aggregate*: Aggregates are the important constituents in concrete that give body to the concrete as a result, reduce shrinkage and effect economy. To know more about the concrete, it is more important to know about the aggregates which constitute major volume of the concrete about 70-80%. Coarse aggregate of singled-size of 19mm passing and 9.5mm retained were used for making no-fines interlocking paving blocks. Aggregates were obtained at the school premises, south campus.

3.1.3 *Water*: Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength, giving cement gel, the quantity and quality of water is required to be looked into very carefully. The water that was used in this study was tap water at the school premises south campus, building department.

3.2 *Mixture* proportions

Production of no-fines concrete samples

Different aggregate/cement ratios that were used for the study are: 4:1, 6:1 and 8:1 with 0.40, 0.42 and 0.45 of water/cement ratios respectively. 18 numbers of no-fines concrete interlocking paving blocks and 3 numbers of no-fines concrete cylindrical samples were produced for each aggregate/cement ratio and were tested at the end of 7days, 14days and 28days.

Table 1: Aggregate/cement and water/cement ratios for no-fine concrete

Cement	Aggregate	Water/cement ratio
1	4	0.40
1	6	0.42
1	8	0.45

Table 2: Batching by weight

S/N	Ratio	Cement(Kg)	Granite(Kg)	Water(Kg)
1	1:4, 0.40	10.80	43.20	4.32
2	1:6, 0.42	7.71	46.29	3.23
3	1:8, 0.45	6.0	48.0	2.70

Procedures for mixing

- Weigh aggregate, cement and water for the mix.
- Moisten the working concrete surface to prevent water absorption.
- Add the aggregate to the concrete surface and add approximately half the water and mix until all the aggregate is wet.
- Spread the cement and water uniformly over the surface of the aggregate.
- Mix the concrete until the aggregate is evenly covered with cement paste.
- Clean/rob the interlocking moulds with oil and place the concrete mix in it.
- A slight rodding /tamping is allowed on no-fines concrete mix round the edges and surface of the concrete in the moulds.

- The moulds were left for 24hours to ensure sufficient bonding between the aggregate particles as initial curing.
- Then the samples were removed from the moulds and immersed in water and cured for 7days, 14days and 28days to ensure optimum curing is achieved and each age was tested for compressive strength test, density and tensile strength test.

3.3 *Preparation* of Test Specimens

3.3.1 *Materials* and Methods of Testing

Concrete mixes with different aggregate/cement ratios i.e. 4:1, 6:1 and 8:1 by weight method using weigh balance were prepared using Ordinary Portland cement and a single-sized ordinary dense aggregates fraction from 9.5mm to 19mm. Interlocking block moulds and cylindrical moulds of 150mm x 300mm were used. Tamping or gentle rodding only were used in casting no-fines concrete. Vibration and workability tests cannot be done as a result of the absence of fine aggregate and also due to very little cohesion between the particles. Only a visual check to ensure even coating of all particles was used. The samples made were cured in water for 7days, 14days and 28days, which is very important because of the small thickness of the cement paste involved.

3.3.2 *Compressive* test

One of the most essential tests for concrete is the compressive strength test, which provides significant information about the material's properties. This test offers a comprehensive evaluation of the quality of concrete and is carried out at the Federal Polytechnic Ede, Osun State, in the Concrete Laboratory of the Building Technology Department. The tools used in this test include a compressive testing machine, a shovel, a trowel for mixing, and a tamping rod for compaction (figure 1). The compressive strength of concrete cubes is determined using a universal testing machine with a capacity of 2000 kN, applying a loading rate of approximately 0.9 MPa/sec. The average strength is calculated from three concrete cube samples, each with dimensions 150 mm x 150 mm x 150 mm, fabricated and tested according to ASTM C109 at intervals of 7, 14, and 28 days.

The compressive strength σ is calculated using the formula:

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

where:

- σ: Compressive strength (MPa)
- P: Maximum applied load at failure (N)
- A: Cross-sectional area of the specimen (mm²)

For a 150 mm x 150 mm cube, the cross-sectional area A is:

$$A = 150\text{mm} \times 150\text{mm} = 22500\text{mm}^2$$

This formula allows for accurate calculation of the compressive strength of each concrete cube.

Figure 1(a) Crushing of No-Fines Concrete Interlock Samples (b) Failures of No-Fines Concrete Samples After Crushing

3.3.3 *Indirect* tensile test

The tensile strength of concrete cannot be measured directly. This leads to the need to determine the tensile strength through indirect methods. The indirect tensile test is also referred to as the ‘Brazil’ or splitting test, where a cylinder is placed on its side and broken in the compression machine. This test can also be used to determine the modulus of elasticity of the concrete sample.

Testing Procedure:

1. Measure the diameter (D) and length (L) of the specimen in the plane where it will be tested.
2. Align bearing strips between the testing jig and the specimen to ensure even load distribution.
3. Center the testing jig in the compression machine and lower the top platen.
4. Apply a small force to achieve correct seating.
5. Apply the force at a controlled rate to prevent shock loading.
6. Record the maximum load (P) applied to the concrete before failure.
7. Observe and record the fracture pattern and appearance of the concrete.

The indirect tensile strength T of the specimen is calculated using the following formula:

$T= 2P/\pi LD$.

where:

- T: Indirect tensile strength (MPa)
- P: Maximum applied load at failure (N)
- L: Length of the specimen (mm)
- D: Diameter of the specimen (mm)
- π: Pi, approximately 3.14159

3.3.4 *Density* test

The density of concrete is determined using 150 x 150 x 150 mm cubes following ASTM C 642-13. To measure the dry density, the samples were dried in an oven at 110°C for 24 hours. After drying, the samples were submerged in water for another 24 hours to allow them to reach saturation. Once stable, the samples were weighed in two states: saturated (wet) weight and submerged weight.This research was conducted at 7, 14 and 28 days to determine the density of the concrete samples. Density (ρ) is calculated as follows:

where: $\rho = \frac{W1}{V}$

- ρ: Dry density of the concrete (g/cm^3 or kg/m^3)
- W1: Dry weight of the specimen (g)
- V: Volume of the specimen (cm^3), which for a cube of 150 mm side length is $150\times150\times150=337500$ mm^3 or $337.5cm^3$

4.0 Results and discussion

4.1 *Density*

Single-sized aggregates in no-fines concrete form large interconnected voids distributed throughout the body of the concrete. The porous structure of this type of concrete is responsible for the lower density of no-fines concrete in comparison with the conventional concrete. The density of the investigated concrete varies between 1778 and 2155 kg/m^3, which is lower than the average density of normal-weight concrete ($2400kg/m^3$). The decreased density means lower dead load of the structure. Density decreases with the increase of aggregate-cement ratio as shown in Table 3.

Table 3: Density tests of no-fines concrete interlocking paving blocks at 7days curing for 4:1, 6:1 and 8:1.

S/No	A/C	W/C	Weight(kg)	Volume(m^3)	Density(kg/m^3)	Average(kg/m^3)
A	4:1	0.40	3.20	0.0015	2133	
A	4:1	0.40	3.20	0.0015	2133	2155
A	4:1	0.40	3.30	0.0015	2200	
B	6:1	0.42	2.90	0.0015	1947	
B	6:1	0.42	3.10	0.0015	2067	2005
B	6:1	0.42	3.00	0.0015	2000	
C	8:1	0.45	2.70	0.0015	1800	
C	8:1	0.45	2.80	0.0015	1867	1889
C	8:1	0.45	3.00	0.0015	2000	

Table 4: Density tests of no-fines concrete interlocking paving blocks at 14days curing for 4:1, 6:1 and 8:1.

S/No	A/C	W/C	Weight(k)	Volume(^{3})	Density(kg/m)	Average(kg/m)
A	4:1	0.40	3.00	0.0015	2000	
A	4:1	0.40	3.30	0.0015	2200	2089
A	4:1	0.40	3.10	0.0015	2067	
B	6:1	0.42	2.80	0.0015	1867	
B	6:1	0.42	3.00	0.0015	2000	1911
B	6:1	0.42	2.80	0.0015	1867	
C	8:1	0.45	2.70	0.0015	1800	
C	8:1	0.45	2.65	0.0015	1767	1811
C	8:1	0.45	2.80	0.0015	1867	

Table 5: Density tests of no-fines concrete interlocking paving blocks at 28days curing for 1:4, 1:6 and 1:8.

S/No	A/C	W/C	Weight(kg)	Volume(m^3)	Density(kg/m^3)	Average(kg/m^3)
A	4:1	0.40	3.0	0.0015	2000	
A	4:1	0.40	3.0	0.0015	2067	2044
A	4:1	0.40	3.2	0.0015	2133	

B	6:1	0.42	2.8	0.0015	1867	
B	6:1	0.42	2.9	0.0015	1933	1889
B	6:1	0.42	2.8	0.0015	1867	
C	8:1	0.45	2.7	0.0015	1800	
C	8:1	0.45	2.6	0.0015	1733	1778
C	8:1	0.45	2.7	0.0015	1800	

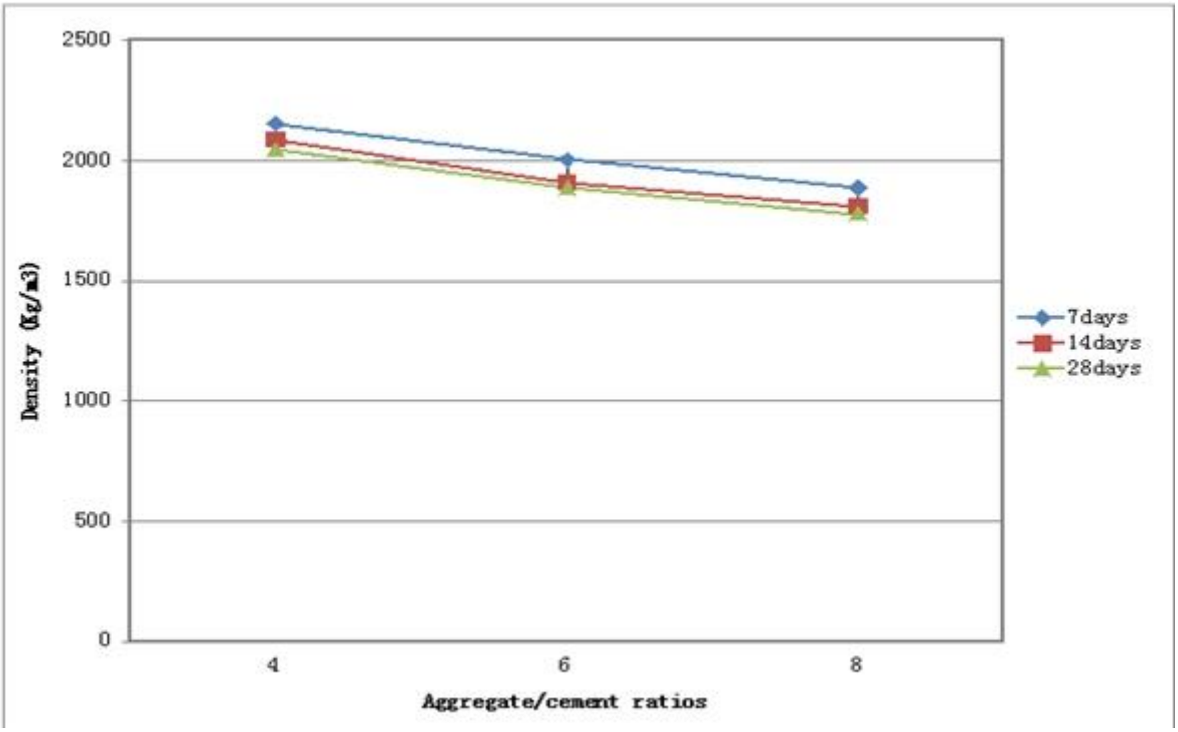

Figure 2: Influence of aggregate/cement ratios on the Density of no-fines concrete interlocking paving blocks

4.2 *Compressive* strength

The compressive strength of no-fines concrete was determined after 7, 14 and 28 days of water curing. Table 6 and Fig. 3 show the influence of aggregate/cement ratio on the compressive strength of no-fines concrete at different ages. Average compressive strength of no-fines concrete at the age of 7days varies between 2.08 and 8.24MPa, depending mainly on aggregate/cement ratio and decreases with the increase of aggregate/cement ratio. Mix with aggregate/cement ratio 4:1 gives the highest strength.

Compressive strength of no-fines concrete was lower than the compressive strength of conventional normal weight concrete due to increased porosity. Also it is observed that the compressive strength of no-fines concrete at 7days gives highest strength than at 14days and 28days i.e. the compressive strength of no-fines interlocking paving blocks decreased with in curing age. Water curing by immersion method was used.

Table 6: Compressive strength of no-fines concrete interlocking paving blocks at 7days curing for 4:1, 6:1 and 8:1.

S/No	A/C	W/C	Weight (kg)	Crushing Load (N)	Area (mm^2)	Compressive Strength (N/mm^2)	Average (N/mm^2)
A	4:1	0.40	3.20	120,000	25,000	4.80	8.24
A	4:1	0.40	3.20	178,000	25,000	7.12	
A	4:1	0.40	3.30	320,000	25,000	12.80	
B	6:1	0.42	2.90	80,000	25,000	3.20	4.21
B	6:1	0.42	3.10	120,000	25,000	4.80	
B	6:1	0.42	3.00	116,000	25,000	4.63	
C	8:1	0.45	2.70	40,000	25,000	1.60	2.08
C	8:1	0.45	2.80	58,000	25,000	2.32	
C	8:1	0.45	3.00	58,000	25,000	2.32	

Table 7: Compressive strength of no-fines concrete interlocking paving blocks at 14days curing for 4:1, 6:1 and 8:1.

S/No	A/C	W/C	Weight (kg)	Crushing Load (N)	Area (mm^2)	Compressive Strength (N/mm^2)	Average (N/mm^2)
A	4:1	0.40	3.00	100,000	25,000	4.00	6.19
A	4:1	0.40	3.30	228,000	25,000	9.12	
A	4:1	0.40	3.10	136,000	25,000	5.44	
B	6:1	0.42	2.80	80,000	25,000	3.20	3.71
B	6:1	0.42	3.00	98,000	25,000	3.92	
B	6:1	0.42	2.80	100,000	25,000	4.00	
C	8:1	0.45	2.70	60,000	25,000	2.48	2.08
C	8:1	0.45	2.65	48,000	25,000	1.92	
C	8:1	0.45	2.80	62,000	25,000	1.84	

Table 8: Compressive strength of no-fines concrete interlocking paving blocks at 28days curing for 4:1, 6:1 and 8:1.

S/ No	A/ C	W/C	Weight (kg)	Crushing Load (N)	Area (mm^2)	Compressive Strength (N/mm^2)	Average (N/mm^2)
A	4:1	0.40	3.0	100,000	25,000	4.00	5.33
A	4:1	0.40	3.0	120,000	25,000	4.80	
A	4:1	0.40	3.2	180,000	25,000	7.20	
B	6:1	0.42	2.8	78,000	25,000	3.12	3.07
B	6:1	0.42	2.9	78,000	25,000	3.12	
B	6:1	0.42	2.8	74,000	25,000	2.96	
C	8:1	0.45	2.7	55,000	25,000	2.20	1.89
C	8:1	0.45	2.6	40,000	25,000	1.60	
C	8:1	0.45	2.7	47,000	25,000	1.88	

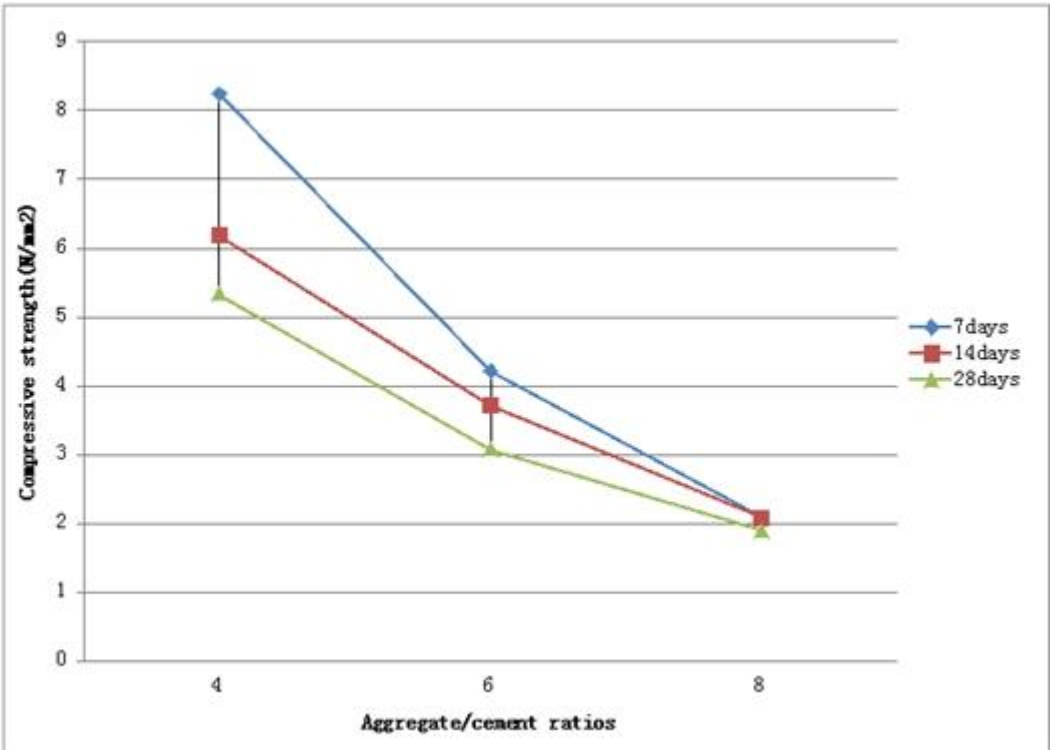

Figure 3: Influence of aggregate/cement ratios on the compressive strength of no-fines concrete interlocking paving blocks

Table 9 and Figure 4 illustrate how curing age affects the compressive strength of no-fines concrete when cured using the water curing method. The data is organized according to three different aggregate-to-cement (A/C) ratios (4:1, 6:1, and 8:1) and across three curing ages (7, 14, and 28 days). Observing these values offers insight into the relationship between curing time, A/C ratios, and compressive strength.

At 7 days, the concrete samples exhibit their highest compressive strength values across all A/C ratios, with the 4:1 ratio yielding the greatest strength at 8.24 MPa, followed by the 6:1 ratio at 4.21 MPa, and the 8:1 ratio at 2.08 MPa. This pattern suggests that a higher cement content (lower A/C ratio) enhances early compressive strength, likely due to better bonding in the concrete matrix.

As curing time progresses to 14 and 28 days, the compressive strength of the samples shows a general decrease rather than the increase often seen in typical concrete mixes. For instance, at 14 days, the 4:1 A/C ratio shows a strength of 6.19 MPa, while the 6:1 and 8:1 ratio exhibit strengths of 3.71 MPa and 2.08 MPa, respectively. By 28 days, compressive strength further decreases, with the 4:1 ratio at 5.33 MPa, the 6:1 ratio at 3.07 MPa, and the 8:1 ratio at 1.89 MPa.

Figure 2 likely illustrates this trend, emphasizing the initial strength gain at 7 days, followed by a decline over subsequent days. This unusual reduction in strength with extended curing time may be attributed to the porous structure of no-fines concrete, which lacks fine aggregates to fill gaps within the matrix. As curing progresses, water may penetrate and weaken these voids, reducing the overall strength.

In summary, the data in Table 9 and Figure 2 reveal that no-fines concrete achieves its peak compressive strength early (at 7 days) and then gradually declines. The A/C ratio plays a critical role, with lower A/C ratios (higher cement content) providing superior compressive strength across all curing ages. This information suggests that for no-fines concrete applications where compressive strength is a priority, a shorter curing time with a lower A/C ratio may be more beneficial.

Table 9: Influence of curing ages on Compressive strength of No-fines concrete

Aggregate/ cement ratio	4:1	6:1	8:1
7days	8.24	4.21	2.08
14days	6.19	3.71	2.08
28days	5.33	3.07	1.89

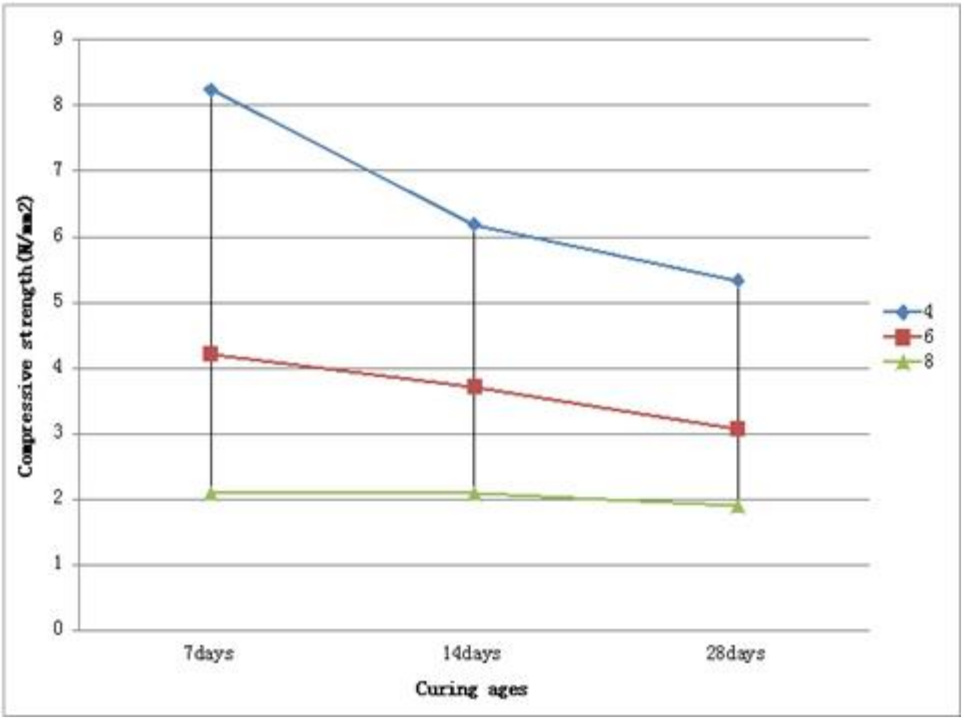

Figure 4: Influence curing ages on the compressive strength of no-fines concrete using water curing method

4.3 *Tensile* test

Table 10 provides a detailed summary of test results, showing the variations in A/C and water-to-cement (w/c) ratios and their corresponding impact on tensile failure force (P). For each sample, the specimen length and diameter were kept consistent at 300 mm and 150 mm, respectively, allowing for a clear comparison of indirect tensile strength values.

Analyzing the data in Table 10 reveals a clear trend: as the A/C ratio increases, meaning there is less cement relative to aggregate, the tensile strength of the concrete decreases. For example, at an A/C ratio of 4:1, the tensile strength as the highest strength of 1.98 MPa, while at an A/C ratio of 8:1, it drops significantly to 1.02 MPa. This pattern suggests that a higher proportion of cement in the concrete mix contributes positively to bonding and tensile strength, whereas a higher aggregate content leads to a reduction in the concrete's tensile capacity.

Figure 3 visually represents this relationship, likely showing a negative correlation between A/C ratio and tensile strength. The graph illustrates how increased A/C ratios (from 4:1 to 8:1) correspond to a noticeable decrease in tensile strength. This indicates that mixes with lower A/C ratios are more effective in achieving higher tensile strength, as they contain more cement for enhanced bonding within the concrete matrix.

In conclusion, the findings underscore the importance of selecting an appropriate A/C ratio for applications requiring sufficient tensile strength. A lower A/C ratio results in greater tensile capacity, which could be advantageous for structural applications where tensile performance is a priority. The study's results provide valuable guidance for mix design adjustments in no-fines concrete.

Table 10: Influence of aggregate cement ratio on tensile strength

S/N		A/C	W/C	Force, P (N)	Length (mm)	Diameter (mm)	Indirect Tensile Strength, T (MPa)
1.		4:1	0.40	140,000	300	150	1.98
2.		6:1	0.42	100,000	300	150	1.42
3.		8:1	0.45	72,000	300	150	1.02

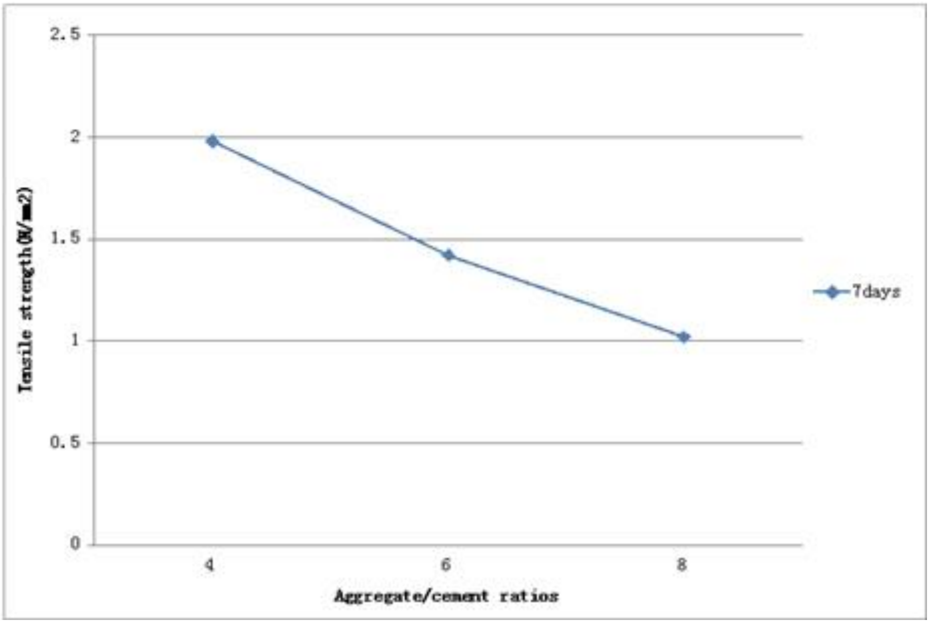

Figure 5: Influence of aggregate/cement ratios on the tensile strength of no-fines concrete

5.0 Conclusion

The study has successfully evaluated the suitability of no-fines concrete interlocking paving blocks for low traffic volume applications. The following conclusions can be drawn from the findings:

1. The water curing method, specifically immersion in a water tank throughout the curing period, was found to be unsuitable for no-fines concrete. Unlike conventional concrete, which typically exhibits increased compressive strength with longer curing times, no-fines concrete demonstrated a decrease in strength as curing age progressed.
2. Due to its low compressive strength, no-fines concrete interlocking paving blocks are recommended for use in low-traffic areas such as footpaths, car parks, and residential streets rather than high-traffic applications.
3. The inherent porosity of no-fines concrete contributes to its ability to deform prior to failure, highlighting a need for careful consideration in its application.
4. The study identified optimal mix ratios for no-fines concrete: an aggregate/cement ratio of 4:1 and a water/cement ratio of 0.40 yield the highest compressive strength while maintaining adequate permeability.
5. The water/cement ratio is crucial for the performance of no-fines concrete; exceeding a ratio of 0.45 may result in drainage of cement paste from aggregate particles, while a ratio lower than 0.40 may not adequately coat the aggregate, compromising strength and integrity.

6.0 Recommendations

Based on the conclusions drawn from this research, the following recommendations are proposed:

1. Further investigation is needed to identify more effective curing methods for no-fines or pervious concrete that enhance strength and performance.
2. Future studies should explore the use of larger and harder aggregates beyond the single-sized aggregates utilized in this research, as they may contribute to improved compressive strength and could affect porosity and permeability rates.
3. It is advisable for future research to focus on aggregate/cement ratios lower than 4:1, including trials with ratios as low as 2:1. Given the high permeability rates observed, it is plausible that these lower ratios could still maintain acceptable permeability levels.
4. The incorporation of local materials and the evaluation of additives in no-fines concrete mixes should be prioritized in future research to enhance performance and sustainability.
5. The impact of aggregate flakiness on the compressive strength of no-fines concrete warrants further investigation, as flaky aggregates are known to negatively influence strength. Identifying low-cost, environmentally friendly alternatives with non-flaky characteristics should also be a focus.
6. Research should explore methods to mitigate or eliminate the raveling that occurs on the surface of no-fines concrete pavements, as this presents a significant drawback in its application.

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