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Comparative Assessment of Two Mix Proportions for Interlocking Concrete Tiles Targeting 30 MPa Characteristic Strength

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Abstract- The performance of interlocking concrete tiles depends strongly on the proportions of cement, water, fine aggregate, and coarse aggregate used in their production. This study investigated two concrete mix proportions developed for interlocking tiles with a target characteristic compressive strength of 30 MPa. River sand in Zone 2 and 10 mm granite chippings were used as fine and coarse aggregates, respectively. The reported specific gravities of the fine and coarse aggregates were 2.66 and 2.71. Two mixes were designed using SCALE 149 software. Mix 1 had a reported proportion of 320:190:760:1195 and a water-to-cement ratio of 0.594, while Mix 2 had a proportion of 275:160:790:1240 and a water-to-cement ratio of 0.58, for cement, water, fine aggregate, and coarse aggregate, respectively. Five bone-shaped specimens were produced for each mix, demoulded after 24 h, cured for 28 days, and tested for compressive strength using a 200 kN compression testing machine. The reported compressive strengths for Mix 1 were 34.0, 37.7, 40.2, 39.6, and 30.7 MPa, giving a mean strength of 36.44 MPa. Recalculation from the five individual results gives a sample standard deviation of 4.02 MPa. Mix 2 produced strengths of 43.7, 34.1, 36.8, 40.2, and 37.4 MPa, with a mean of 38.44 MPa and a sample standard deviation of 3.65 MPa. Using the characteristic-strength approach reported in the source study, $f_{ck} = \bar{f} - Ks$ with K = 1.64, the calculated characteristic strengths are 29.85 MPa for Mix 1 and 32.45 MPa for Mix 2. Thus, Mix 2 was the preferred mix among the two investigated proportions because it exceeded the 30 MPa target while using less cement than Mix 1. The findings provide a practical basis for selecting a mix proportion for interlocking concrete tiles, although the limited number of specimens warrants further validation with larger experimental datasets and additional durability tests.

Keywords— interlocking concrete tiles; mix proportion; compressive strength; characteristic strength; water-cement ratio; paver blocks.

I. INTRODUCTION

Interlocking concrete paving units are widely used for pedestrian areas, residential compounds, parking areas, roads, and other paved surfaces. Their suitability depends on material quality, unit geometry, production and compaction, curing, and concrete mix proportion. BS EN 1338 specifies requirements and test methods for unreinforced concrete paving blocks, including materials, properties, mechanical performance and conformity assessment [1].

Published research shows that mix composition and production variables materially affect paving-unit performance. Poon and Lam [2] reported that compressive strength of precast concrete blocks decreased as the aggregate-to-cement ratio increased and that aggregate characteristics influenced strength and water absorption. Ohemeng and Yalley [3] found that water-cement ratio was an important variable in predicting density and compressive strength of concrete pavement blocks. Production method is also important: Widayanto et al. [4] found that vibropressing duration and frequency significantly affected compressive strength. These findings support evaluating mix proportion together with manufacturing and curing conditions rather than attributing performance to cement content alone.

Recent studies in Nigeria and other developing-country contexts have investigated conventional and alternative materials for interlocking pavers. Olofinnade et al. [5] examined steel-slag replacement of natural sand and reported changes in compressive and tensile performance. Olofinnade et al. [6] investigated periwinkle and palm-kernel shells in load-bearing interlocking pavers, targeting 30 MPa at 28 days, and demonstrated the importance of material selection and curing. Gana et al. [7] showed that cement brand can influence strength development of interlocking paving stones produced in Nigeria. Karthik et al. [8] reviewed strength, durability, aggregate selection and alternative materials as recurring themes in interlocking paver research. In the literature reviewed for this study, however, the direct comparison of two conventional cement-river-sand-granite proportions developed around a 30 MPa characteristic-strength target is less prominent. The present study therefore focuses on this practical comparison using the reported experimental results.

II. LITERATURE REVIEW

Poon and Lam [2] investigated the effects of aggregate-to-cement (A/C) ratio and aggregate type on precast concrete blocks. Their experiments showed that compressive strength increased as the A/C ratio decreased, while aggregate strength also influenced block strength. They further reported that aggregate type affected density and water absorption. This study is directly relevant because the two mixes considered here differ in the relative quantities of cement and aggregate. It supports the interpretation that the higher performance of Mix 2 cannot be attributed to cement content alone; the overall balance of cement, fine aggregate and coarse aggregate must also be considered.

Ohemeng and Yalley [3] developed models for predicting the density and compressive strength of rubberized concrete pavement blocks and identified water-cement ratio as an important variable affecting performance. Although their work incorporated rubber as an alternative material, the finding is applicable to conventional paving-block studies because changes in water content alter the cement paste structure and the resulting strength. In the present investigation, Mix 2 had a lower reported water-cement ratio of 0.58 than Mix 1 at 0.594, and it also produced the higher mean and calculated characteristic strengths.

Widayanto et al. [4] examined the effect of vibropressing compaction on concrete paving blocks and reported that compaction duration and frequency significantly influenced compressive strength. Their findings demonstrate that paving-block performance is not controlled by mix proportion alone. Compaction determines particle packing and the internal structure of the hardened unit. Consequently, comparison of mix proportions should be interpreted alongside specimen preparation and compaction conditions. The present study therefore reports its layer placement and 25-stroke tamping procedure so that the experimental conditions are transparent.

Olofinnade et al. [5] investigated the use of steel slag as a partial replacement for natural sand in interlocking concrete paving blocks. Using a 1:1.5:3 cement:sand:granite proportion and a constant water-cement ratio of 0.50, they assessed several replacement levels and demonstrated the feasibility of incorporating steel slag in paver production. Olofinnade et al. [6] later investigated periwinkle shell and palm-kernel shell as partial replacements for granite in load-bearing interlocking pavers. Their study targeted 30 MPa at 28 days and used a 1:1:2 cement:sand:granite control mix with a water-cement ratio of 0.50. These studies are important because they show that a 30 MPa target is practical for interlocking pavers and that aggregate selection can materially change performance.

Gana et al. [7] evaluated different cement brands in the production of interlocking paving stones in Nigeria and monitored strength development at different curing ages. Their work demonstrated that cement source or brand can influence the strength achieved by otherwise similar paving-stone mixtures. This indicates that reproducibility of a mix proportion requires adequate identification and control of the cement used. In the present study, cement is treated as a principal constituent of both mixes, while the main comparison is between the reported proportions.

Karthik et al. [8] reviewed interlocking paver blocks and identified strength, durability, aggregate selection and alternative materials as recurring areas of investigation. More broadly, Bilir et al. [9] reviewed research on interlocking concrete block paving containing industrial and agricultural wastes and considered compressive, flexural and tensile strength together with water absorption, abrasion, freeze-thaw, thermal resistance and other durability indicators. Their review highlights that compressive strength is important but should not be considered the only performance criterion for paving units. This supports the present study's decision to treat the compressive-strength comparison as a screening result rather than as complete evidence of field suitability.

Solouki et al. [10] applied a Design of Experiments approach to optimize concrete paving blocks containing waste silt. They produced multiple aggregate blends and subsequently evaluated the selected mixture using EN 1338-related physical and mechanical tests, including water absorption, tensile splitting strength, abrasion and skid resistance. Their work demonstrates the value of testing several combinations systematically when the objective is true mix optimization. By contrast, the present study compares only two pre-existing conventional proportions. Therefore, the result should be described as selection of the better of two investigated mixes, not as universal optimization.

The reviewed studies consistently show that interlocking concrete-paver performance is affected by several interacting variables: aggregate-to-cement ratio and aggregate quality [2], water-cement ratio [3], compaction [4], aggregate substitution and material type [5,6], cement source [7], and durability-related properties beyond compressive strength [8,9]. Optimization-oriented studies also demonstrate that a wider experimental matrix and multiple performance tests are required when a general optimum is to be established [10]. However, the reviewed literature contains comparatively fewer direct comparisons of two conventional cement-river-sand-granite proportions selected around a 30 MPa characteristic-strength target and evaluated using the same production procedure. The present study addresses this narrower practical question by comparing two reported proportions under controlled specimen preparation and 28-day compressive testing. The literature therefore provides the basis for interpreting the observed difference between Mix 1 and Mix 2 while also defining the limits of the conclusions that can reasonably be drawn.

III. MATERIALS AND METHODS

1. Materials

The fine aggregate used in the study was river sand reported to fall within Zone 2, with a specific gravity of 2.66. The coarse aggregate was 10 mm granite chippings with a reported specific gravity of 2.71. Cement and water were used as the remaining principal constituents of the concrete mixes.

2. Mix Design

Two concrete mixes were designed for a target characteristic strength of 30 MPa. The source study reports that SCALE 149 software was used for the mix-design calculations. The design inputs included standard deviations of 4 and 6 MPa, a slump range of 10–30 mm, and the measured specific gravities of the aggregates. The two investigated proportions are summarized in Table 1.

Mix	Cement	Water	Fine aggregate	Coarse aggregate	w/c ratio
Mix 1	320	190	760	1195	0.594
Mix 2	275	160	790	1240	0.580

Note: The quantity for coarse aggregate in Mix 2 is reported as 1240 in the discussion and summary of the original manuscript; the abstract contained an inconsistent value of 240. The value 1240 has been used consistently in this revised manuscript. The original manuscript also did not explicitly state the unit basis of the tabulated mix quantities; the numerical proportions are therefore presented as reported rather than assigned a new unit.

3. Specimen Preparation and Testing

Bone-shaped concrete tile specimens were cast in moulds that had been cleaned and lightly lubricated. The moulds were filled in layers, with each layer compacted by 25 tamping strokes. After 24 hours, the specimens were demoulded and cured for 28 days. Five specimens were produced for each mix proportion. After curing, the specimens were tested using a 200 kN compression testing machine. The original study reported that compressive strength testing followed BS EN 12390-3:2002.

4. Statistical Analysis

Compressive strength was calculated from the maximum load sustained by a specimen divided by its loaded cross-sectional area. The mean compressive strength was calculated as:

$$\bar{f} = \Sigma f_i / n$$

where $\bar{f}$ is the mean compressive strength, Σf_i is the sum of the individual compressive strengths, and n is the number of specimens. The sample standard deviation was calculated as:

$$s = \sqrt{[\Sigma(f_i - \bar{f})^2 / (n - 1)]}$$

Data-check note: The individual compressive-strength values were independently recalculated before the statistical summary was prepared. This correction affects the sample standard deviations and derived characteristic strengths, but not the ranking of the two mixes.

The source study used $f_{ck} = \bar{f} - Ks$ for characteristic strength with K = 1.64. Recalculation from the individual specimen results gives a sample standard deviation of 4.02 MPa for Mix 1 and 3.65 MPa for Mix 2, corresponding to characteristic strengths of 29.85 MPa and 32.45 MPa, respectively. These recalculated values are used in this revised manuscript because the standard deviations and characteristic strengths reported in the source manuscript are not mathematically consistent with the individual measurements.

IV. RESULTS

1. Compressive Strength Results

Specimen	Mix 1 strength (MPa)	Mix 2 strength (MPa)
1	34.0	43.7
2	37.7	34.1
3	40.2	36.8
4	39.6	40.2
5	30.7	37.4
Mean	36.44	38.44
Standard deviation	4.02	3.65
Characteristic strength	29.85	32.45

The individual results show that Mix 2 produced a higher mean compressive strength than Mix 1. Mix 1 had a mean of 36.44 MPa, whereas Mix 2 had a mean of 38.44 MPa. Recalculation of the individual results gives sample standard deviations of 4.02 MPa and 3.65 MPa, respectively.

2. Comparison with the Target Strength

Mix	Mean strength (MPa)	Standard deviation (MPa)	Characteristic strength (MPa)	Target (MPa)	Target achieved?
Mix 1	36.44	4.02	29.85	30	No
Mix 2	38.44	3.65	32.45	30	Yes

Mix 1 produced a calculated characteristic strength of 29.85 MPa, which is slightly below the 30 MPa target. Mix 2 produced 32.45 MPa and therefore exceeded the target by 2.45 MPa. Mix 2 also used less cement than Mix 1, with a lower water-cement ratio of 0.58 compared with 0.594.

V. DISCUSSION

The results indicate that the two mix proportions produced different levels of compressive performance. This is consistent with published evidence that aggregate-to-cement ratio and water-cement ratio influence paving-block strength [2,3], while compaction and curing conditions also affect measured performance [4,6]. Although both mixes produced mean compressive strengths above 30 MPa, the characteristic-strength calculation differentiates the mixes because it accounts for variability among specimens. Mix 1 had a calculated characteristic strength of 29.85 MPa and therefore did not reach the 30 MPa target under the calculation approach used in this study. Mix 2 achieved 32.45 MPa and was consequently the only mix of the two to exceed the target characteristic strength.

The lower water-cement ratio of Mix 2 is consistent with its higher mean and characteristic strengths. However, the difference in water-cement ratio between the mixes is relatively small, and the study involved only five specimens per mix. Therefore, the results should be interpreted as a comparison of the two investigated proportions rather than as a definitive optimization across all possible mix combinations.

An important practical advantage of Mix 2 is its lower cement content. The reported proportions contain 275 units of cement for Mix 2 compared with 320 units for Mix 1, while Mix 2 achieved the higher mean and characteristic strengths. This direction of result is compatible with the broader literature showing that the balance between binder and aggregate affects paving-block strength [2]. However, the present data are not sufficient to establish a general optimum cement content or a statistically generalized mix-design law.

The experimental scope is limited to compressive strength. Other properties relevant to interlocking pavement products, including water absorption, abrasion resistance, flexural performance, dimensional stability, and long-term durability, were not reported. Further experimental work should therefore evaluate these properties before broad field application or specification of the mix for particular pavement classes.

VI. CONCLUSION

Two concrete mix proportions were investigated for the production of interlocking concrete tiles with a target characteristic compressive strength of 30 MPa. Mix 1, with a water-cement ratio of 0.594, produced a mean compressive strength of 36.44 MPa, a sample standard deviation of 4.02 MPa, and a calculated characteristic strength of 29.85 MPa. Mix 2, with a water-cement ratio of 0.58, produced a mean compressive strength of 38.44 MPa, a sample standard deviation of 3.65 MPa, and a calculated characteristic strength of 32.45 MPa. Consequently, Mix 2 was the preferred mix among the two investigated proportions because it exceeded the 30 MPa target and used less cement. The result should be regarded as a selection between the two tested mixes rather than a universal optimum. Additional specimens and durability-related tests are recommended before the mix is adopted for wider engineering applications.

Limitations and Recommendations

The principal limitation of the study is the small experimental sample size of five specimens per mix. The investigation also focuses on compressive strength and does not report durability, abrasion, water absorption, or field-performance data. Future studies should test a larger number of specimens, examine additional water-cement ratios and aggregate proportions, and evaluate durability and service-performance properties under representative environmental and loading conditions.

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