Integrated Science Education Journal
Vol. 7, No. 3, May 2026, pp. 536~546
ISSN: 2716-3725, DOI: 10.37251/isej.v7i3.3116

Research Article

Empirical Correlation of Compressive and Flexural Strengths in 20 Mpa Rigid Pavement Concrete: Effects of Varied Cement Brands and South Sumatra Local Aggregates

Efrilia Rahmadona[1,*], Kiki Rizky Amalia[1], Norca Praditya[1], Rio Marpen[1], Anadia Septiani[1], Muhammad Hanif[1], Nanda Wulandari[1]
[1] Civil Engineering Department, Politeknik Negeri Sriwijaya, Sumatera Selatan, Indonesia

Article Info

Article history:

Received Mar 16, 2026
Revised Apr 21, 2026
Accepted May 22, 2026
OnlineFirst May 31, 2026

Keywords:

Brand Variation
Conversion Coefficient
Local Aggregates Cement
Mechanical Property
Rigid Pavement

ABSTRACT

Purpose of the study: The study aims to determine empirical conversion coefficients between compressive strength (f'c) and flexural strength (fs) for a 20 MPa rigid pavement concrete design and to evaluate the specific effects of local South Sumatra aggregates combined with three distinct regional cement brands.

Methodology: Laboratory experimental methods utilized 18 specimens (9 cylinders, 9 beams). Aggregates underwent sieve analysis, specific gravity testing, and moisture testing in accordance with SNI standards. Mechanical tests used a compressive strength machine and a two-point loading flexural apparatus. Materials comprised Musi River sand, Baturaja gravel, and Baturaja, Tiga Roda, and Dynamix cements. Data analysis used linear regression models.

Main Findings: All variations exceeded the 20 MPa design target. Dynamix cement achieved the highest mean compressive strength (26.23 MPa), while Baturaja cement produced the highest mean flexural strength (3.22 MPa). The derived empirical conversion coefficients (fs $\sqrt{f'c}$) were 0.67 for Baturaja, 0.66 for Tiga Roda, and 0.62 for Dynamix. The collective correlation yielded a linear regression equation of $y = 0.0219x + 2.6131$ with $R^2 = 0.2731$.

Novelty/Originality of this study: This study establishes unique, brand-specific empirical conversion factors for pavement concrete formulated with unique South Sumatra regional aggregates. It directly advances existing engineering knowledge by demonstrating how localized combinations of raw materials deviate from generalized national standard formulas, enabling field engineers to confidently perform rapid quality control without resource-intensive on-site beam trial mixes.

Corresponding Author:
Efrilia Rahmadona,
Civil Engineering Department, Politeknik Negeri Sriwijaya,
Jl. Srijaya Negara, Bukit Lama, Kec. Ilir Bar. I, Palembang, Sumatera Selatan, 30128, Indonesia
Email: efriliarahmadona@polsri.ac.id

1. INTRODUCTION

Concrete stands as the cornerstone of Indonesia's infrastructure development, particularly within the highway construction sector where it serves as the primary material for rigid pavements designed to endure heavy traffic loads [1], [2]. Structurally, the performance and durability of these pavements are governed by two fundamental mechanical parameters: compressive strength (f'c) and flexural strength (fs) [3], [4]. Although flexural strength is the more representative indicator of a pavement’s real-world capacity to resist bending moments induced by traffic axles, standard field specifications and mix designs continuously default to compressive strength as their baseline quality control metric [5], [6].

This operational reliance on compressive strength creates a prominent practical challenge during field execution. Relying strictly on compressive testing creates an empirical mismatch in rigid pavement design, where structural failure modes are predominantly governed by bending and tensile stresses rather than pure axial compression [4], [7]. Project contractors are frequently forced to execute resource-intensive beam trial mixes or intrusive, destructive core-drill evaluations to confirm whether the cured concrete satisfies the mandatory flexural requirements, a process that inherently delays project timelines and escalates operational budgets [8], [9]. Consequently, establishing an accurate, empirical mathematical model to directly convert compressive properties into flexural properties is vital for construction efficiency [10], [11]. However, generalized conversion formulas provided by global and national codes, such as ACI 318 or SNI 2847:2013, often fall short. Prior studies indicate that code-defined equations frequently overestimate or underestimate the actual flexural capacity because they assume a homogeneous relationship across all material types, completely neglecting localized aggregate physics [1], [12]. Furthermore, variations in chemical composition and mineralogical phases across different commercial cement brands significantly disrupt the uniform development of the compressive-to-flexural strength ratio [13], [14]. This problem is heavily compounded when localized regional aggregates, which possess unique surface textures and mineral contents, alter the internal bond structure of the Interfacial Transition Zone (ITZ), rendering global prediction equations highly unreliable for site-specific engineering applications.

The explicit gap in the existing literature lies in the complete unavailability of a localized empirical conversion model that simultaneously incorporates the cross-interaction of regional geological aggregates and inter-brand cement chemical variations. Standard design equations assume that raw materials behave homogeneously across regions. In reality, the mineralogy, surface roughness, and particle shape of specific regional aggregates alter the interfacial transition zone (ITZ) within the concrete matrix. While the combination of South Sumatra’s local materials specifically fine aggregate from the Musi River and coarse gravel from Baturaja is heavily utilized in regional infrastructure, its precise mechanical correlation with different mainstream commercial cement brands for a target 20 MPa pavement grade remains entirely unexplored in structural engineering literature.

To address this gap, this investigation evaluates the mechanical strength relationships of a 20 MPa rigid pavement concrete mix using a controlled laboratory matrix. The primary objective of this study is to isolate and derive localized, brand-specific conversion coefficients (α = fs √f’c) tailored for concrete incorporating Musi River sand, Baturaja gravel, and three dominant regional cement brands (Baturaja, Tiga Roda, and Dynamix). By establishing these localized empirical conversion equations, this study aims to provide field engineers in South Sumatra with a practical, non-destructive quality control tool, thereby eliminating the necessity for repetitive, costly, and time-consuming beam testing on active job sites. Based on the identified problems and objectives, this research addresses two primary questions, first how do variations in localized commercial cement brands alter the independent development of compressive and flexural strengths when combined with South Sumatra aggregates?, and What precise empirical equations define the structural correlation between f’c and fs within this specific material boundary?.

2. RESEARCH METHOD

In this study, testing of fine aggregate (sand), coarse aggregate (aggregate), cement, and concrete test samples was conducted at the Civil Engineering Laboratory of Sriwijaya State Polytechnic, situated on the campus in Bukit Besar, Palembang, South Sumatra Province. The research was conducted using local materials for concrete mixtures, including fine aggregate (sand) sourced from the Musi River and coarse aggregate (aggregate) sourced from the Baturaja area, as well as three brands of cement: Baturaja, Tigaroda, and Dynamix. The materials were prepared for testing at the Civil Engineering Laboratory of Sriwijaya State Polytechnic.

Fine aggregate is an aggregate in which all particles pass through a 4.75 mm sieve (ASTM C33, 1982) [15], [16]. In this study, local sand was collected from the Musi River, Palembang, South Sumatra Province. To determine the sand gradation, sieve analysis was first conducted by sieving, followed by tests for specific gravity, water absorption, moisture content, and silt content [15]. Coarse aggregate is aggregate in which all particles are retained on a 4.75 mm sieve (ASTM C33, 1982) [16], [17]. The split material was sourced from the Baturajam area in South Sumatra Province. Physical testing was conducted first to determine the split gradation, which involved a sieve analysis test using a sieve, followed by specific gravity and water absorption tests, as well as tests for moisture and silt content [18].

Cement is a complex industrial product, with different mixtures and compositions [19]. Cement can be categorized into two distinct classifications: non-hydraulic cement and hydraulic cement. Non-hydraulic cement is incapable of binding and hardening in water; however, it is capable of hardening in air. Conversely, hydraulic cement has the capacity to bind and harden in water [16], [20]. The cements used in this study were Baturaja, Tigaroda, and Dynamix cements. Furthermore, the cement underwent specific gravity testing, cement consistency testing, and cement setting time testing.

Concrete is a composite material composed of a use a mixture of Portland cement or another hydraulic cement, fine aggregate, coarse aggregate, and water, with or without incorporation additives are necessary [21], [22]. A total of nine cylindrical samples were collected. Nine beam samples were prepared for testing. Material specimens (sand, aggregate, and cement) were subjected to physical testing. The testing of sand and split samples included sieve analysis, moisture content and silt content, specific gravity and water absorption. The cement materials were subjected to rigorous testing to ascertain their specific gravity, consistency, and setting time. The afore mentioned tests are referenced in the SNI 03-2834-2000 guideline, which delineates the procedures for preparing standard concrete mix designs [23]. As shown in Table 1.

Table 1. Aggregate and Cement Testing Standards

No	Testing	Standard
1	Test Methods for Sieve Analysis of Fine Aggregate and Coarse Aggregate [24]	SNI ASTM C136:2012
2	How to Test the Specific Gravity and Water Absorption of Coarse Aggregates [25]	SNI 1969:2008
3	How to Test the Specific Gravity and Water Absorption of Fine Aggregates [26]	SNI 1970:2008
4	Testing Method for Bulk Density and Air Void Content in Aggregates [27]	SNI 03-4804-1998
5	Testing Method for Moisture Content and Silt Content in Aggregates [28]	SNI 03-1971-1990
6	Portland Cement Specific Gravity Testing Method	SNI 15-2531-1991
7	Method for Testing the Normal Consistency of Portland Cement Using a Vicat Apparatus for Civil Engineering Works	SNI 03-6826-2002
8	Method for Testing the Initial Setting Time of Portland Cement Using a Vicat Apparatus for Civil Engineering Works	SNI 03-6827-2002

Aggregate sieve analysis testing is conducted to determine the gradation, sieve pass percentage, and fineness modulus (FM) [29]. The equation for determining the Fineness Modulus value is:

$$FM = \frac{\%Retained\ Agreggate}{100} \dots (1)$$

Specific gravity and water absorption tests are conducted to determine whether the sand and split used meet the specifications for concrete mixes, where the specific gravity for normal aggregates is 2.5–2.7 and the maximum water absorption value is 3%. The silt content in the aggregate will also affect the strength of the concrete; therefore, silt content and water content tests must be carried out, with a maximum silt content tolerance of 5% for sand and 1% for the aggregate. Furthermore, physical tests for cement include testing the specific gravity of cement according to SNI 15-2531-1991, which is 3.00–3.2 for portland cement. This study employs a true experimental laboratory research design to investigate the mechanical property correlations of concrete. To resolve previous inconsistencies, the sampling method used is a purposive sampling technique (structured experimental matrix selection).

The sample size was systematically determined based on the replication requirements of the Indonesian National Standard (SNI 03-2834-2000) for concrete mix designs [30]. A total of 18 concrete specimens were fabricated, divided equally into two distinct geometry types: 9 standard cylinders (15 x 30 cm) for compressive testing and 9 standard beams (60 x 15 x 15 cm) for flexural testing. The samples were clustered into three experimental groups based on the cement brand utilized: Baturaja Cement (BA), Tiga Roda Cement (TR), and Dynamix Cement (DY). Each group contains exactly 3 identical replicates to ensure statistical reproducibility and to monitor the coefficient of variation within the experimental batches. As shown in Table 2, the test specimens are differentiated based on the cement brand used, consisting of Baturaja Cement (BA), Tigaroda Cement (TR), and Dynamix Cement (DY).

Table 2. Number of Test Items

Compressive Strength (MPa)	Number of Test Items (Cylinders)			Number of Test Items (Beams)		
	BA	TR	DY	BA	TR	DY
20	3	3	3	3	3	3
Total		9			9	

After the concrete test specimens were made, the curing process was carried out by soaking the concrete and then waiting for the compressive strength and flexural strength tests to be conducted 28 days after the concrete was molded[31]. The cylinder concrete testing process refers to the concrete compressive strength test method using cylinder test specimens, as specified in SNI 1974:2011. The compressive strength test used a compressive strength[32]. The compressive strength of concrete is defined as the unit load that causes the concrete to break [33]. Concrete compressive strength testing will be conducted following a 7-, 28-, and 56-day aging period. The distribution of the working load will be continuous, with the load being applied along the longitudinal axis of the cross-section. The stress will be equivalent to the fc value, which is defined as the maximum compressive load divided by the cross-sectional area of the test piece [34].

$$Fc = \frac{P}{A} \dots (2)$$

In this equation, fc denotes the compressive strength of the concrete cylinder, P represents the maximum compressive load (Newtons), and A signifies the cross-sectional area of the test specimen (centimeters squared per millimeter squared). The concrete beam test is a standard method of evaluating the flexural strength of concrete, as outlined in SNI 4431:2011, which stipulates two loading points.

Flexural strength is defined as the ability of a concrete beam placed on two supports to withstand a force perpendicular to the axis of the test specimen, applied to it, until the test specimen breaks [35], [36]. This force is expressed in Mega Pascal (MPa) force per unit area [37]. A beam under load will undergo deformation, and therefore, bending moments arise as resistance from the material forming the beam against the external load. It is imperative that the stress that arises during deformation does not exceed the bending stress. The objective of this mission is to ascertain the properties of concrete materials. It is imperative that external moments be supported by concrete materials. The maximum price that can be achieved before the beam collapses or breaks is equal to the internal support moment of the beam [38].

The data analysis strategy focuses on mapping the empirical path from compressive performance to flexural output. the data analysis tool chosen for this study is Microsoft Excel Analysis ToolPak to execute Simple Linear Regression Analysis and empirical coefficient curve fitting. This statistical software is fully justified for physical material science correlations where the objectives are to calculate: a) The empirical conversion coefficient (α) for each individual cement brand using the formula : α = fs /√f'c; b) The overall global predictive linear regression equation: y = mx + c; c) The coefficient of determination (R^2) to evaluate the goodness-of-fit and quantify the exact percentage of variation in flexural strength that can be explained by the variation in compressive strength.

3. RESULTS AND DISCUSSION

The initial phase involved identifying the physical properties of local materials from South Sumatra to understand their baseline quality prior to casting. The results of aggregate property testing include sieve analysis, specific gravity, and water absorption. The results of these tests indicate that aggregate sieve analysis is a test used to determine whether the gradation of sand and aggregate meets specifications. Sieve analysis testing will determine the Fineness Modulus (FM) value. As shown in Table 3, the following are the results of the sieve analysis tests for aggregate (coarse aggregate) and sand (fine aggregate).

Table 3. Sieve Analysis

Sieve Size	Cumulative Retained Aggregate (%)		Cumulative Passed Aggregate (%)	
	Coarse Aggregate	Fine Aggregate	Coarse Aggregate	Fine Aggregate
37.5	0.00		100.00	
19	21.00		79.00	
12.5	76.5		23.25	
9.5	89.00		11.00	
4.75	0.00	0.00		100.00
2.36	0.00	0.87		99.13
1.18	0.00	4.15		15.85
0.60	0.00	35.99		64.01
0.30	0.00	91.81		8.19
0.15	0.00	97.78		2.22
0.08	0.00	99.23		0.77
Pan	100.00	100.00		
	286.75	329.83		

The results of sieve analysis testing for coarse aggregate indicate a Fineness Modulus (FM) value of 2.85, as defined in SNI ASTMC136-2012. The range of FM values for coarse aggregate is from 5.5 to 8.5, as per the aforementioned standard. Preliminary findings indicate that the Fineness Modulus value for the coarse aggregate has not been met [39]. Concurrently, the Fineness Modulus value for fine aggregate (sand) is 3.29. Preliminary analysis of the test results indicates that the Fineness Modulus value of the fine aggregate is within the specified range of 1.5 to 3.8. The experimental findings, as evidenced by the test results for specific gravity and water absorption, demonstrate that the aggregate meets the specification of 2.5 to 2.7, thereby indicating that its specific gravity is in accordance with the standard for normal aggregate [40]. As shown in Table 4 dan Table 5.

Table 4. Specific Gravity and Absorption

No	Aggregate Type	Bulk	Saturated Surface Dry	Apparent Density	Absorption (%)
1	Coarse Aggregate	2.62	2.68	2.77	1.47
2	Fine Aggregate	2.21	2.50	3.12	8.79

Based on the results of testing, the average moisture content in coarse aggregate is 0.42%, which met the specifications of <3%. In comparison, the test results for the silt content of 3.75% indicate that the silt content of the coarse aggregate does not meet the specification of a maximum silt content of 1%. The materials used for concrete mixtures should meet the specifications, especially the requirement that the organic content does not exceed 1% because it will affect the planned compressive strength. Therefore, if coarse aggregate material is to be used for the mixture, it should be washed first to reduce the clay content. On the other hand, the test results for the acceptable aggregate water content were 3.24%, indicating that the water content in the fine aggregate was still relatively high and did not meet the specification of < 3%. The silt content was 3.23%, indicating that the clay content in the fine aggregate remained within the maximum tolerance of 5% [40].

The initial stage involves identifying the physical properties of local materials from South Sumatra to understand their basic quality prior to the casting process. Based on the data presented earlier, the physical properties of the materials from the sieve analysis are briefly summarized as follows. Sieve analysis indicated a Fineness Modulus (FM) of 3.29 for the Musi River fine aggregate, positioning it securely within the standard 1.5–3.8 grading zone. However, its water absorption (8.79%) and moisture content (3.24%) exceeded standard targets, reflecting the highly porous nature of river-bed sediments. For the Baturaja coarse aggregate, the FM recorded was 2.85, accompanied by a silt content of 3.75%, which surpassed the standard 1% limit. To mitigate this and prevent clay minerals from disrupting the Interfacial Transition Zone (ITZ), the coarse aggregates were thoroughly washed before mixing

Furthermore, the results of testing the properties of cement, specifically its specific gravity, consistency, and setting time, are presented in Table 5. In this study, three brands of cement were used: Baturaja, Tigaroda, and Dynamix.

Table 5. Cement Density

No	Cement Type	Cement Density
1	Baturaja	3.09
2	Tigaroda	2.78
3	Dynamix	3.05

The specific gravities of Baturaja and Dynamix cements, as determined by the test results, were 3.09 and 3.05, respectively. As shown in Table 6, the specific gravity values met the specifications, which range from 3.00 to 3.25. Meanwhile, the specific gravity value of Tigaroda cement did not meet the specifications, at 2.78.

Table 6. Consistency of Cement

No	Cement Type	Consistency of Cement (%)
1	Baturaja	25
2	Tigaroda	26
3	Dynamix	25

The mean cement consistency value was 25%. This finding suggests that the quantity of water necessary to bind the cement was 125 grams. The results of the setting time test demonstrated that Baturaja cement exhibited the fastest setting time. To address the first research question, the independent development of compressive strength (f'c) and flexural strength (fs) was systematically monitored 28 days post-curing. The experimental data revealed that while all mixtures successfully surpassed the structural target of 20 MPa, the choice of cement brand induced highly distinct mechanical variations. The compressive strength test results are shown in Table 7 and Figure 1.

Table 7. Compressive Strength

Test Item (Cylinder)	Compressive Strength		Average Compressive Strenght
	N/mm^2	MPa	MPa
BA 1	24.63	24.63	
BA 2	24.06	24.06	23.40
BA 3	21.51	21.51	
TR 1	21.23	21.23	
TR 2	23.21	23.21	21.99
TR 3	21.51	21.51	
DY 1	25.76	25.76	
DY 2	26.04	26.04	26.23
DY 3	26.89	26.89	

The findings of the compressive strength testing indicated that the specimens manufactured with various cement brands exhibited distinct compressive strengths [41], [42]. The concrete specimens mixed with Dynamix cement achieved the highest mean compressive strength at 26.23 MPa, followed by Baturaja cement at 23.40 MPa, and Tiga Roda cement at 21.99 MPa. Interestingly, an inverse performance trend was observed during flexural beam testing. The highest mean flexural tensile strength was achieved by the Baturaja cement matrix (3.22 MPa), followed closely by Dynamix cement (3.13 MPa), and Tiga Roda cement (3.03 MPa).

Figure 1. Compressive Strength Testing

The chemical composition of the cement used in the concrete also affects its compressive strength [43]. To assess the mechanical properties of the test materials, a series of flexural strength tests were performed on the test specimens. These tests were conducted after a 28-day curing process, which is a standard protocol in material science and engineering research [44]. As shown in Figure 2, the testing was carried out using a specialized machine that employed a 2-point loading method[41],[45].

Figure 2. Flexural Strength Testing

The results of the flexural strength test are shown in the Table 8

Table 8. Flexural Strength

Test Item (Beam)	Flexural Strength (MPa)	Average Flexural Strength (MPa)
BA 1	3.23	
BA 2	2.95	3.22
BA 3	3.48	
TR 1	2.95	
TR 2	3.17	3.03
TR 3	2.97	
DY 1	2.91	
DY 2	3.28	3.13
DY 3	3.21	

From a materials science perspective, this divergence can be explained by differences in chemical composition and mineralogical ratios (specifically Tricalcium Silicate C3S and Dicalcium Silicate C2S) across the commercial brands. Brands prioritizing early-to-mid-term compressive strength often favor higher C3S fractions to accelerate Calcium-Silicate-Hydrate (C-S-H) gel deposition under axial compression. Conversely, flexural capacity is highly sensitive to micro-crack propagation across the binder-aggregate boundary. The superior flexural performance of Baturaja cement indicates a highly compatible chemical affinity with local Baturaja gravel, producing a denser ITZ that effectively resists localized shear and tensile cleavage during two-point bending.

To answer the second research question, the direct mathematical path linking compressive data to flexural performance was established using linear regression modeling as shown in Figure 3, the highest mean flexural strength was observed in the beam test specimens fabricated with the Baturaja brand cement mixture, yielding an average of 3.22 megapascals (MPa), which is equivalent to 32 megapascals (MPa)[46]. The relationship between compressive strength and flexural strength produced from three different cement brands demonstrated that the highest compressive strength was achieved by Dynamix cement at 25.76 MPa, followed by Baturaja cement at 23.40 MPa, and the lowest compressive strength was achieved by Tigaroda cement at 21.23 MPa. However, all test specimens exhibited compressive strength values that met the stipulated target of 20 MPa. Conversely, the flexural strength test results indicated that the Baturaja cement brand exhibited the highest flexural strength value of 3.22 MPa, followed by Dynamix cement with 3.13 MPa, and the lowest flexural strength value of 3.03 MPa was observed with the use of Tigaroda cement. This finding suggests that the utilization of local fine and coarse aggregates, in conjunction with market cement of the appropriate composition, can attain the desired concrete quality and potentially surpass it.

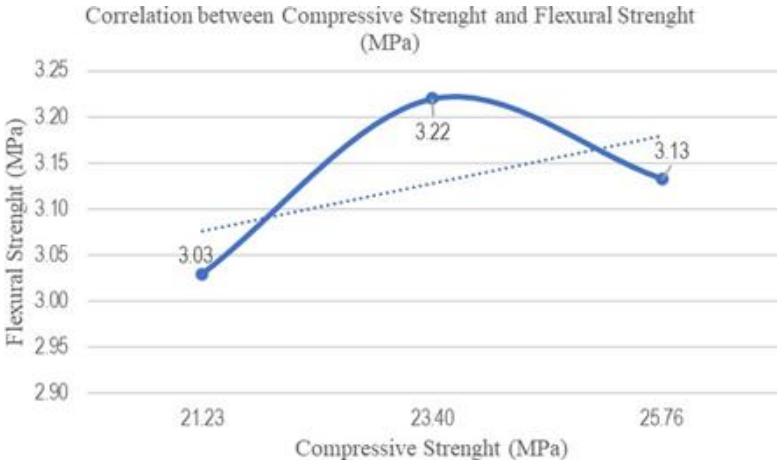

Figure 3. Correlation Graph between Compressive Strength and Flexural Strength.

As shown in Figure 4, the relationship between concrete compressive strength and concrete flexural strength is obtained using simple linear regression analysis, as illustrated in the following graph. The regression equation is $y = 0.0219x + 2.6131$, and the R2 value is 0.2731[47], [48].

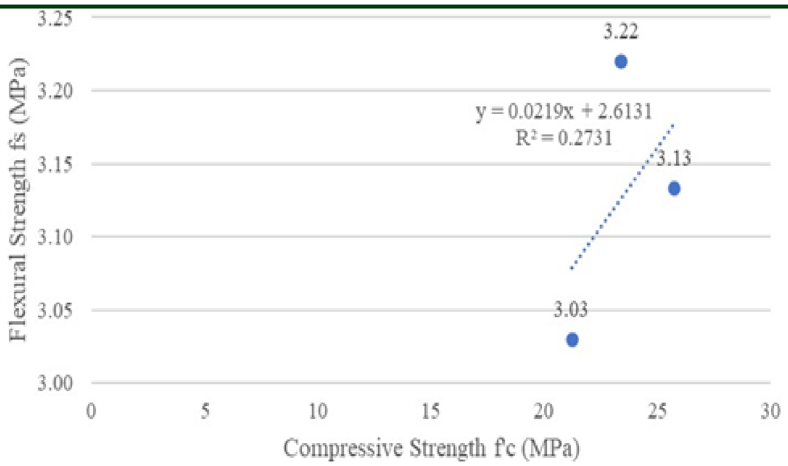

Figure 4. Regression Analysis

Where x represents f'c and y represents fs. The calculated coefficient of determination (R^2) was 0.2731. In physical material science, an R^2 value of 0.2731 indicates that a generalized linear trend exists, but a single global equation cannot fully capture the variations introduced by different cement brands. This statistical finding strongly justifies the need to isolate brand-specific empirical conversion coefficients ($\boldsymbol{\alpha}$) rather than relying on one uniform formula.

Comparison of flexural strength with compressive strength based on the test results obtained a correlation value of compressive strength and flexural strength for each test specimen [49], [50].

Table 9. Correlation of Compressive Strength and Flexural Strength

Test Item (Cylinder)	Compressive Strength (f'c)	Flexural Strength (fs)	Correlation of Compressive Strength and Flexural Strength	
	N/mm^2	MPa	$\sqrt{fc}$	$\frac{fs}{\sqrt{fc}}$
TR	21.23	3.03	4.61	0.66
BA	23.40	3.22	4.84	0.67
DY	25.76	3.13	5.08	0.62

When compared against national standard baselines, the mean conversion coefficient across all batches closely aligns with the standard empirical constant of 0.62 stipulated in SNI 2847-2013 (fs = 0.62√f'c). However, the individual deviations particularly the elevated (α) values of 0.67 and 0.66 for Baturaja and Tiga Roda cements demonstrate that generalized national formulas tend to underestimate the flexural capacity of concrete configured with local South Sumatra materials. This confirms the alternative hypothesis, proving that inter-brand chemical variations alter the conversion ratio.

According to the test results, the correlation values for compressive strength and flexural strength were obtained for each test specimen . For the use of Tigaroda cement, the correlation value was 0.66, for Baturaja cement, 0.67, and for Dynamix cement, 0.62. Based on the Table of values obtained in the study, the average results were the same as those in SNI 2847-2013. For the correlation result of fc'20 MPa 28 days of 0.62√fc', it was in accordance with SNI 0.62√fc' [51]. This study advances existing structural knowledge by moving beyond generic code assumptions that treat concrete components as structurally homogeneous. Prior works by Saputra [1] for Bojonegoro aggregates reported localized conversion factors as low as 0.46, while standard national guidelines dictate a fixed 0.62 value. The clear novelty of this study is the mapping of brand-specific conversion boundaries for moderate-grade (20 MPa) rigid pavements using the unique regional aggregate pairing of Musi River sand and Baturaja gravel. The results prove that concrete utilizing identical local aggregates can display different conversion mechanics depending on the binder brand. This adds a critical new layer to concrete mix design theory, demonstrating that the conversion coefficient is a dynamic variable governed by the mineralogical compatibility between localized aggregates and proprietary commercial cement compositions.

For civil engineering practitioners and infrastructure authorities in South Sumatra, these findings offer immediate practical value. Current field protocols require project teams to cast and cure large beam specimens to verify flexural compliance for rigid pavement approvals a process that is time-consuming and often slows down construction timelines. By applying the brand-specific empirical coefficients developed in this study (e.g., using

0.67√f’c for Baturaja cement setups or 0.62√f’c for Dynamix setups), field engineers can confidently predict flexural pavement performance directly from standard, easily executed cylinder compressive tests. This eliminates the necessity for heavy, resource-intensive field beam testing matrices, reduces material waste, accelerates project delivery speeds, and maintains strict quality control over regional highway infrastructure. Despite its valuable contributions, this study has limitations that should be noted. The experimental matrix was bounded by a single target strength grade of 20 MPa at a fixed 28-day curing interval, using specific aggregate sources from the Musi River and Baturaja area. Furthermore, due to equipment limitations, the underlying causes of strength variations across cement brands were inferred based on mechanical macro-behavior rather than direct chemical quantification. To build upon these findings, future research should expand the experimental framework to evaluate higher structural grades (e.g., 30 MPa and 45 MPa) across extended curing lifespans of 56 and 90 days to map long-term conversion shifts. Additionally, integrating microstructural characterization tools such as Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD)—is highly recommended to visually analyze the interfacial transition zone and precisely quantify the mineralogical compounds responsible for these brand-specific mechanical performance differences.

4. CONCLUSION

This study successfully fulfills its primary objective by establishing localized empirical conversion models between compressive strength (f’c) and flexural strength (fs) for a 20 MPa rigid pavement concrete design utilizing South Sumatra aggregates. The laboratory investigations conclusively demonstrate that all experimental mixtures surpassed the 20 MPa structural threshold. While Dynamix cement generated the highest compressive strength (26.23 MPa), Baturaja cement achieved the highest flexural performance (3.22 MPa). Crucially, the isolated empirical conversion coefficients (α = fs /√f’c) varied distinctively across binders, yielding 0.67 for Baturaja cement, 0.66 for Tiga Roda cement, and 0.62 for Dynamix cement, with a global regression baseline defined as $y = 0.0219x + 2.6131$ ($R^2 = 0.2731$). Based on these empirical facts, this study produces a new qualitative engineering concept: The Binder-Aggregate Mineralogical Compatibility Concept. This concept posits that the mechanical strength conversion boundary of concrete is not a static, uniform constant dictated solely by structural grade (as generalized by national building codes like SNI 2847-2013). Instead, it is a dynamic properties matrix controlled by the proprietary chemical-mineralogical compatibility between specific commercial cement brands and the physical topography of localized geological aggregates, which directly dictates the density and micro-cleavage resistance of the Interfacial Transition Zone (ITZ).The structural and economic implications of these findings are highly significant for infrastructure management in South Sumatra. By adopting these brand-specific conversion factors (particularly the elevated 0.67 and 0.66 coefficients), civil engineering practitioners and regional transport authorities can transition away from traditional, costly, and time-consuming on-site beam fracture testing. Field quality control can be executed non-destructively by accurately predicting real-time flexural performance directly from standard cylinder compressive tests. This significantly minimizes material waste, reduces structural test overheads, and accelerates the construction and approval timelines of regional rigid highway pavement projects without compromising structural safety margins.

ACKNOWLEDGEMENTS

We would like to thank the Institute for Research and Community Services, Sriwijaya Polytechnic, which funded this study through the 2025 Innovation Research Grant with Contract No , dated 26 June 2025.

AUTHOR CONTRIBUTIONS

ER, KRA, designed the study, conducted the analysis, collected the data, and analyzed data. NP, RM wrote the manuscript. AS, MH, and NW supported the availability of research data.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

[1] I. H. Saputra, “Analisis hubungan nilai konversi fc’dan fs dengan uji kuat tekan dan lentur beton studi material lokal Kabupaten Bojonegoro [Analysis of the relationship between the conversion values fc' and fs with the compressive and flexural strength tests of concrete in a study of local materials in Bojonegoro Regency],” *Innov. J. Soc. Sci. Res*., vol. 3, pp. 5479–5489, 2023, doi: https://doi.org/10.31004/innovative.v3i3.

[2] E. Rahmadona, K. R. Amalia, L. Ulfah, and N. Praditya, “Analisis kuat tekan beton dengan pemanfaatan silica fume dan fly ash sebagai pengganti semen sebagian [Analysis of concrete compressive strength using silica fume and fly ash as partial cement replacements],” *Talenta*, vol. 7, no. 1, pp. 217–223, 2024, doi: 10.33087/talentasipil.v7i1.451.

[3] B. Bharoto, H. Hanan, and A. Widyowijatnoko, “Institutionalising concrete construction technology: A socio-technical formation of modern architecture in Indonesia,” *History of science and technology*, vol. 15, no. 2, 2025, doi: 10.32703/2415-7422-2025-15-2-396-425.

[4] K. I. Pratama, P. R. T. Naibaho, and S. Bangun, “Hubungan kuat tekan dan kuat lentur beton dengan mutu fc’ 25 megapascal (mpa) [Relationship between compressive strength and flexural strength of concrete with quality fc' 25 megapascals (mpa)],” *Indones. J. Constr. Eng. Sustain. Dev*., vol. 6, no. 1, pp. 1–7, 2023, doi: 10.25105/cesd.v6i1.17151.

[5] M. E. Nunn, A. Brown, D. Weston, and J. C Nicholls, *Design of long-life flexible pavements for heavy traffic*. TRL Limited, 1997.

[6] D. Waluyo, I. L. Elviyanti, T. Maemunah, and A. A. Syukron, “Study of compressive and flexural strength of concrete using bima cement for national road reconstruction in Kebumen,” *Int. J. Mech. Electr. Civ. Eng*., vol. 2, pp. 179–186, 2025, doi: 10.61132/ijmecie.v1i1.145.

[7] M. S. Meteab, A. A. Mansor, and W. D. Salman, “Effect of concrete compressive strength on the behavior of reinforced concrete beams with different cross-sections,” *AIP Conf. Proc*., vol. 2787, no. 1, pp. 80033, 2023, doi: 10.1063/5.0150162.

[8] R. Evin, “The ratio between flexural strength to compressive strength of geopolymer concrete The ratio between flexural strength to compressive strength of geopolymer concrete,” in *The 8th International Conference of Euro Asia Civil Engineering Forum 2022*, 2022, pp. 1–8. doi: 10.1088/1755-1315/1195/1/012034.

[9] S. Suhendra and F. Fadlan, “Perencanaan, pelaksanaan dan evaluasi mutu beton perkerasan kaku [Planning, implementation and evaluation of rigid pavement concrete quality],” *Jurnal Civronlit Unbari*, vol. 7, no. 2, pp. 91–96, 2022, doi: 10.33087/civronlit.v7i2.103.

[10] D. Falliano, D. De Domenico, G. Ricciardi, and E. Gugliandolo, “Compressive and flexural strength of fiber-reinforced foamed concrete: Effect of fiber content, curing conditions and dry density,” *Constr. Build. Mater*., vol. 198, pp. 479–493, 2019, doi: 10.1016/j.conbuildmat.2018.11.197.

[11] E. V. Muho, N. D. Beskou, and J. Qian, “Models and methods for dynamic response of 3D flexible and rigid pavements to moving loads: A review by representative examples,” *J. Road Eng*., vol. 5, no. 1, pp. 65–91, 2025, doi: 10.1016/j.jreng.2024.07.003.

[12] R. Campos, M. M. M. Larrain, M. Zaman, and V. Pozadas, “Relationships between compressive and flexural strengths of concrete based on fresh field properties,” *Int. J. Pavement Res. Technol*., vol. 14, no. 2, pp. 161–167, 2021, doi: 10.1007/s42947-020-1074-0.

[13] Q. Xu, S. Liu, J. Qian, R. Xu, and W. Ma, “Effects of three different types of fibers and dosage on the properties of alkali-activated copper slag – slag cementitious materials,” *Nature*, pp. 1–18, 2025, doi: 10.1038/s41598-025-11384-1.

[14] C. R. Marín-Uribe and R. Navarro-Gaete, “Empirical relationships between compressive and flexural strength of concrete containing recycled asphalt material for pavement applications using different specimen configurations,” *Materiales de Construcción*, vol. 71, no. 342, 2021, doi: 10.3989/mc.2021.11520.

[15] A. Bhatt, S. Priyadarshini, A. Acharath Mohanakrishnan, A. Abri, M. Sattler, and S. Techapaphawit, “Physical, chemical, and geotechnical properties of coal fly ash: A global review,” *Case Stud. Constr. Mater*., vol. 11, p. e00263, 2019, doi: 10.1016/j.cscm.2019.e00263.

[16] T. Mulyono, *Teknologi Beton: Dari Teori Ke Praktek [Concrete Technology: From Theory to Practice]*, 2018.

[17] C. Hettiarachchi, and W. Mampearachchi, *Handbook of Asphalt Technology*. Springer, 2025.

[18] R. P. Chapuis, “Analyzing grain size distributions with the modal decomposition method: literature review and procedures,” *Bull. Eng. Geol. Environ*., vol. 80, no. 9, pp. 6649–6666, 2021, doi: 10.1007/s10064-021-02328-w.

[19] E. Purnamasari, A. Gazali, and M. B. Januar, “The effect of variations of fly ash filling materials on porous concrete using local aggregates from South Borneo,” *IOP Conf. Ser. Earth Environ. Sci*., vol. 999, no. 1, 2022, doi: 10.1088/1755-1315/999/1/012002.

[20] N. Makul, Introduction to the principles of cement and concrete composites. In *Principles of Cement and Concrete Composites* (pp. 1-27). Cham: Springer International Publishing, 2021, pp. 1–27. doi: 10.1007/978-3-030-69602-3_1.

[21] S. P. Machmoed and U. Khatulistiani, “The potential of styrogravel concrete as a new concrete material for building structures,” *IOP Conf. Ser. Mater. Sci. Eng*., vol. 434, no. 1, 2018, doi: 10.1088/1757-899X/434/1/012193.

[22] M. B. Revuelta, *Construction materials: Geology, production and applications*. Springer Nature, 2021.

[23] SNI 03-2834-2000, “SNI 03-2834-2000: Tata cara pembuatan rencana campuran beton normal [SNI 03-2834-2000: Procedures for making a normal concrete mix plan],” Sni 03-2834-2000, pp. 1–34, 2000.

[24] ASTM C136:2012, “ASTM C136:2012 Metode uji untuk analisis saringan agregat halus dan agregat kasar [ASTM C136:2012 Test method for sieve analysis of fine and coarse aggregates],” Badan Stand. Nas., pp. 1–24, 2012.

[25] SNI 1969, *Cara Uji Berat Jenis dan Penyerapan Air Agregat Kasar [How to Test Specific Gravity and Water Absorption of Coarse Aggregate]*, Badan Standar Nas. Indones., p. 20, 2016.

[26] SNI-03-1970-1990, *Metode Pengujian Berat Jenis dan Penyerapan Air Agregat Halus [Testing Method for Specific Gravity and Water Absorption of Fine Aggregate]*. Keputusan Menteri Pekerjaan Umum 2000.

[27] SNI 03-4804-1998, *Metode Pengujian Bobot Isi dan Rongga Udara dalam Agregat [Testing Method for Bulk Density and Air Voids in Aggregates]*. Keputusan Menteri Pekerjaan Umum, 1998.

[28] S. 03-1971-1990, *Metode Pengujian Kadar Air Agregat [Aggregate Moisture Content Testing Method]*. Keputusan Menteri Pekerjaan Umum 1990.

[29] A. Osouli, P. Adhikari, E. Tutumluer, and H. Shoup, “Properties of aggregate fines influencing modulus and deformation behaviour of unbound aggregates,” *Int. J. Pavement Eng*., vol. 22, no. 4, pp. 498–513, 2021, doi: 10.1080/10298436.2019.1623402.

[30] Y. Prima et al., “Penyuluhan komposisi campuran beton untuk jalan tol [Counseling on concrete mix composition for toll roads],” *J. Soc. Work Empower*., vol. 2, no. 3, 2023, doi: 10.58982/jswe.v2i3.429.

[31] B. Liu, J. Jiang, S. Shen, F. Zhou, J. Shi, and Z. He, “Effects of curing methods of concrete after steam curing on mechanical strength and permeability,” *Constr. Build. Mater*., vol. 256, p. 119441, 2020, doi: 10.1016/j.conbuildmat.2020.119441.

[32] L. E. J. Antonia, A. B. P. Gawei, O. Meilawaty, R. Waluyo, “Analysis of concrete compressive strength using local aggregates in the analisis kuat tekan beton menggunakan agregat lokal di Kecamatan Tewah Kabupaten Gunung Mas,” *J. Serambi Eng*., vol. No 4, 2023, doi: 10.32672/jse.v8i4.6989.

[33] D. Z. Yankelevsky, “The uniaxial compressive strength of concrete : revisited,” *Mater. Struct*., vol. 57, no. 6, pp. 1–18, 2024, doi: 10.1617/s11527-024-02422-x.

[34] SNI-1974, *Cara Uji Kuat Tekan Beton dengan Benda Uji Silinder,SNI 1974-2011 [How to Test Concrete Compressive Strength with Cylindrical Test Specimens, SNI 1974-2011]*, Badan Stand. Nas. Indones., pp. 20, 2011.

[35] V. E. Delpia, P. Sakti, and E. S. Maladeni, “Analysis of metal fiber testing with pondidaha coarse aggregate and konawe fine aggregate against flexural strength (Beams),” *SINOMICS J*., vol. 1, no. 3, pp. 357–368, 2022, doi: 10.54443/sj.v1i3.34.

[36] M. A. Al-Osta, M. N. Isa, M. H. Baluch, and M. K. Rahman, “Flexural behavior of reinforced concrete beams strengthened with ultra-high performance fiber reinforced concrete,” *Constr. Build. Mater*., vol. 134, pp. 279–296, 2017, doi: 10.1016/j.conbuildmat.2016.12.094.

[37] R. Ismy, H. Husaini, S. M. Saleh, and M. Isya, “Analysis of the effect of using wire mesh layers on hot asphalt mixtures with modulus of elasticity,” *IOP Conf. Ser. Mater. Sci. Eng*., vol. 1087, no. 1, pp. 012018, 2021, doi: 10.1088/1757-899x/1087/1/012018.

[38] B. S. N. SNI 4431, *SNI 4431-2011 Cara Uji Kuat Lentur Beton Normal dengan Dua Titik Pembebanan [SNI 4431-2011 Test Method for Flexural Strength of Normal Concrete with Two Loading Points]*, Badan Standar Nas. Indones., pp. 1–16, 2011.

[39] M. T. B. Sujatmiko, *Teknologi Beton dan Bahan Bangunan [Concrete Technology and Building Materials]*, Media Sahabat Cendekia, 2019.

[40] L. Yu, Z. Xiaodong, Y. Zhanping, M. Biao, and G. Fangyuan, “Determining aggregate grain size using discrete-element models of sieve analysis,” *Int. J. Geomech*., vol. 19, no. 4, pp. 4019014, 2019, doi: 10.1061/(ASCE)GM.1943-5622.0001376.

[41] M. Zaheer, R. Zhao, S. Sadozai, and F. Zhu, “Case studies in construction materials research on the influence of curing strategies on the compressive strength and hardening behaviour of concrete prepared with ordinary portland cement,” *Case Stud. Constr. Mater*., vol. 18, no. January, pp. e02045, 2023, doi: 10.1016/j.cscm.2023.e02045.

[42] I. S. Fuad, A. Perwira, and H. Jayusman, “Pengaruh pemakaian semen dan pasir yang berbeda terhadap kuat tekan beton [The effect of using different cement and sand on the compressive strength of concrete],” *Desiminasi Teknol*., vol. 8, pp. 8–12, 2023, doi: 10.52333%2Fdestek.v8i1.578.

[43] T. Rudnicki, “The influence of the type of cement on the properties of surface cement concrete,” *Materials*, vol. 15, no. 14, pp. 4998, 2022, doi: 10.3390/ma15144998.

[44] M. M. Gad and S. M. Fouda, “Factors affecting flexural strength of 3D-printed resins: A systematic review,” *J. Prosthodont*., vol. 32, no. S1, pp. 96–110, 2023, doi: 10.1111/jopr.13640.

[45] A. M. Mohamed, “Influence of nano materials on flexural behavior and compressive strength of concrete,” *HBRC J*., vol. 12, no. 2, pp. 212–225, 2016, doi: 10.1016/j.hbrcj.2014.11.006.

[46] Z. Fang, X. Tian, and F. Peng, “Flexural strength of prestressed Ultra-High-Performance concrete beams,” *Eng. Struct*., vol. 279, pp. 115612, 2023, doi: 10.1016/j.engstruct.2023.115612.

[47] V. Revilla-cuesta, R. Serrano-l, A. B. Espinosa, V. Ortega-l, and M. Skaf, “Analyzing the relationship between compressive strength and modulus of elasticity in concrete with ladle furnace slag,” *Buildings*, vol. 13, no. 12, pp. 3100, 2023, doi: 10.3390/buildings13123100.

[48] U. Khasanah, *Analisis regresi [Regression analysis]*. Uad Press, 2021.

[49] M. O. Mohsen, M. M. Al-Diseet, M. O. Aburumman, M. T. Abdel-Jaber, R. Taha, M. S. Al Ansari, and A. A. Taqa, “Hybrid effect of GNPs, GOs, and CNTs on the flexural and compressive strengths of cement paste,” *J. Build. Eng*., vol. 73, pp. 106679, 2023, doi: 10.1016/j.jobe.2023.106679.

[50] A. Bensaber, Z. Boudaoud, N. Toubal, and Ł. Sadowski, “The assessment of concrete subjected to compressive and flexural preloading using nondestructive testing methods, correlation between concrete strength and combined method (SonReb),” *Measurement*, vol. 222, 2023, doi: 10.1016/j.measurement.2023.113659.

[51] N. Praditya and E. Rahmadona, “Sosialisasi evaluasi penggunaan material lokal pada beton hasil pengujian kuat tekan lentur [Socialization of evaluation of the use of local materials in concrete based on flexural compressive strength testing results],” *Darmabakti: Jurnal Inovasi Pengabdian dalam Penerbangan*, vol. 6, pp. 19–23, 2025, doi: 10.52989/darmabakti.v6i1.247.