

# SIGNIFICANCE OF PAVEMENTS, CONCRETE PAVEMENTS, AND SELF-COMPACTING CONCRETE (SCC)

Harsh Wadia<sup>1</sup>, Mr. Rajesh Chouhan<sup>2</sup>

Research Scholar, Department of Civil Engineering, School of Engineering & Technology, Vikram University Ujjain<sup>1</sup>.

Assistant Professor, Department of Civil Engineering, School of Engineering & Technology, Vikram University Ujjain<sup>2</sup>.

## Abstract

*This study investigated the performance of self-compacting concrete (SCC) using different brands of Portland limestone cement, emphasizing rheological, compressive, flexural, and tensile strengths. The results revealed that Brand A cement, with its higher calcium oxide content, provided superior compressive strength and improved rheological properties compared to other brands. This underscores the importance of cement composition, particularly calcium oxide levels, in enhancing SCC's strength and workability. Rheological tests showed that SCC 4 excelled in viscosity, segregation, and passing ability, meeting EFNARC (2006) standards. Furthermore, SCC 1, utilizing Brand A cement, met the compressive strength requirements for pavement construction at 28 days and achieved the highest flexural strength. Additionally, SCC 1 demonstrated the highest tensile strength, crucial for preventing cracking and ensuring structural stability. These findings highlight the significant impact of cement quality on SCC performance, with Brand A emerging as the most effective for achieving high-strength concrete.*

**Keyword:** Self-Compacting Concrete (SCC)<sup>1</sup>, Portland Limestone Cement<sup>2</sup>, Rheological Properties<sup>3</sup>, Compressive Strength<sup>4</sup>, Flexural Strength<sup>5</sup>.

## 1. Introduction

Pavements play a crucial role in infrastructure, providing the essential foundation for roads and airfields. Concrete pavements, known for their durability and strength, are often preferred over other materials due to their long-term performance and resistance to heavy loads. Among the various types of concrete used, self-compacting concrete (SCC) has emerged as a significant innovation, characterized by its ability to flow and consolidate under its own weight, eliminating the need for mechanical vibration. This property is particularly advantageous in complex or densely reinforced structures, where conventional concrete may face challenges in achieving proper compaction. SCC's performance is highly influenced by the quality of the cement used, as it affects both the rheological properties and the mechanical strengths of the concrete. Portland limestone cement, commonly used in SCC, varies in composition, which can significantly impact the concrete's behavior. This study focuses on evaluating the

performance of SCC made with different brands of Portland limestone cement, analyzing aspects such as rheological characteristics, compressive strength, flexural strength, and tensile strength. The aim is to identify how variations in cement composition influence SCC properties and determine the most effective cement for high-performance concrete.

## 2. Methodology

**Experimental material:** In the experimental work, locally available 4.75mm size aggregates were used as fine aggregate. For airfield concrete pavement, the minimum required cement content depends on the maximum size of aggregates (MSA). In this study, with an MSA of 19 mm, the required cement content was minimal. Portable water, free from toxins and harmful materials, was used throughout the research. Mix ingredients and proportions followed EFNARC (2002) guidelines. Four brands of Portland limestone cement (CEM II/A-L and CEM II/B-L) available in the Nigerian market and conforming to ASTM (2013) standards were utilized. One plain SCC mixture was designed with a water-to-cement (w/c) ratio of 0.38, with fine and coarse aggregates prepared according to the rational mix design method by Ozawa et al. (1995). The four cement brands were labeled as SCC 1, 2, 3, and 4. Brand A is Grade 42.5, while the others are Grade 32.5. The concrete's rheology was assessed using the slump cone, V-funnel, and L-box as per ASTM (2013) and EFNARC (2002) specifications. To achieve the desired workability, several trials were conducted, varying the water-cement ratio and superplasticizer dosage while keeping the aggregate mass constant. CONPLAST superplasticizer, as per EFNARC (2006) specifications, was used to enhance workability. Compressive and flexural tests were conducted using 150mm × 150mm × 150mm and 100mm × 400mm × 100mm molds, respectively, with oil applied to the mold interiors to prevent sticking. The concrete was mixed and cured following ASTM (2011) standards.

## 3. Result and discussion

According to Table 1, Brand C had the lowest levels of alkaline oxides, which could potentially affect its strength properties, as suggested by the author. Among the selected brands and grades of cement, Brand A contained a higher amount of calcium oxide compared to the other two brands. This higher calcium oxide content may influence the cement's strength and setting time. The physical properties are detailed in Table 2. Brand A exhibited the highest compressive strength, and the compositions of silicon and aluminum oxides also had implications for strength.

**Table 1: Chemical composition of the cement brands**

Parameters	Brand A	Brand B	Brand C	Brand D
Potassium Oxide	0.34	0.32	0.37	0.35
Silicon Oxide	19.07	21.3	20.05	20.28
Sodium Oxide	0.42	0.54	0.6	0.58
Calcium Oxide	64.52	64.22	63.84	63.79

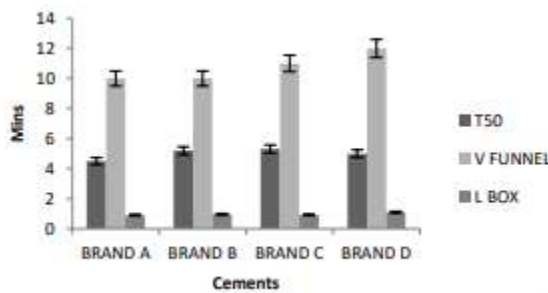
Iron Oxide	0.72	0.85	0.63	0.94
Magnesium Oxide	2.2	2.1	1.98	2.02
Manganese Oxide	0.08	0.07	0.02	0.05
Aluminium Oxide	4.96	4.6	4.97	4.51

**Table 2: Physical properties of the cements**

Cement Brands	Consistency	Initial Setting Time	Final Setting Time	Compressive Strength
Brand A	30	45 min	395 min	46.6 MPa
Brand B	30	51 min	405 min	36.7 MPa
Brand C	30	55 min	465 min	34.4 MPa
Brand D	30	61 min	554 min	29.8 MPa

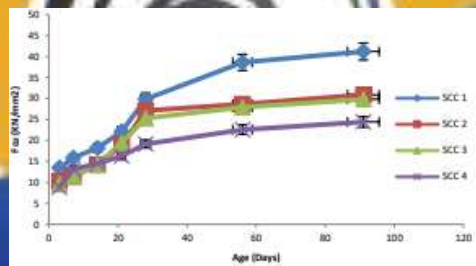
**Rheological Properties of Cement Brands**

Slump flow indicates the flowability of the mix. EFNARC (2002) standards were used to evaluate the rheological properties of self-compacting concrete (SCC). Brand A's slump flow (T50) was outside the specified range of 2-5 seconds, whereas the other three brands fell within this limit (Fig. 3). All four SCC samples met the V-funnel criteria, with results falling within the acceptable range of 6-12 seconds as per EFNARC (2002) specifications, indicating satisfactory viscosity and filling ability. The L-box test, used to assess the passing and filling ability of the concrete mix, showed that SCC 1, SCC 2, SCC 3, and SCC 4 fell within the standard range of 0.8-1. However, SCC 2's L-box result was outside this range (Fig. 1). Overall, only SCC 4 demonstrated good rheological properties, meeting specifications for viscosity (T50), segregation, and passing ability according to EFNARC (2006) standards. The variations in rheological properties among the brands can be attributed to their chemical compositions. Specifically, the higher calcium oxide content in Brands A and B, compared to Brand C, likely increased the setting time and reduced workability, affecting the rheological results.



**Fig. 1: Rheological properties of the selected brand of cement**

**Compressive Strength of SCC Mixes:** Wright (1996) recommends a compressive strength of 27.6 kN/mm<sup>2</sup> for concrete used in pavement construction. Figure 2 illustrates the compressive strength results of the SCC mixes at various curing ages. The analysis revealed that SCC 1, made with cement Brand A, achieved this strength at 28 days of curing, indicating its suitability for rigid pavement construction. In contrast, SCC 2, SCC 3, and SCC 4, which used other cement brands, did not meet the specification for pavement construction at 28 days. This discrepancy may be attributed to the grade and chemical composition of the cement brands. Brands A and B, with higher levels of calcium oxide, aluminum oxide, and silicon oxide, could affect the clinker and gypsum content, which are critical for cement strength. Despite this, they met the requirements for reinforced concrete structures. SCC 1 and SCC 4, using Brands A and C respectively, exhibited high early strength, while SCC 2 had the lowest early strength at 11.35 kN/mm<sup>2</sup>. However, SCC 4 had the lowest compressive strength at maturity.



**Fig. 2: Compressive strength of the selected brand at maturity**

The results indicated that only SCC 1, using cement Brand A, met the specified compressive strength required for pavement construction at maturity. Conversely, in some developing countries like Nigeria, construction workers often prioritize brand names over cement grades, as noted by Adewole et al. (2014). This practice can lead to the use of lower-grade cement, negatively impacting strength. Table 3 presents the descriptive statistics for the compressive strengths of the four SCC mixes with the selected Portland limestone cements. The table includes the mean, median, standard deviation, skewness, kurtosis, Jarque-Bera values, and their corresponding probability values. The statistical analysis after 91 days showed that the mean compressive strength for the four SCC mixes ranged from 18.47 to 30.60 kN/mm<sup>2</sup>. The median values ranged from 19.14 to 32.82 kN/mm<sup>2</sup>. The standard deviations for the SCC mixes indicated significant variability around the mean, suggesting high variability in compressive strength. The normality test, using Jarque-Bera statistics, confirmed the results. The skewness and kurtosis values indicated that the compressive strength data are positively skewed and platykurtic.

**Table 3: Descriptive statistics of the compressive strength of the SCC samples**

Statistic	SCC 1	SCC 2	SCC 3	SCC 4
Mean	30.607	22.10444	21.64	18.47
Median	32.82	27.1	25.3	19.14

<b>Maximum</b>	45.1	29.8	29.5	24.2
<b>Minimum</b>	13.44	10.21	9.55	8.82
<b>Std. Dev.</b>	12.41084	8.38848	8.04998	5.58168
<b>Skewness</b>	-0.19797	-0.40725	-0.43846	-0.42886
<b>Kurtosis</b>	1.52481	1.39044	1.50325	1.84448
<b>Jarque-Bera</b>	0.87486	1.22028	1.12848	0.77659
<b>Probability</b>	0.64569	0.54328	0.56879	0.67821
<b>Sum</b>	275.463	198.94	194.76	166.23
<b>Sum Sq. Dev.</b>	1232.232	562.9328	518.4178	249.2408
4o				

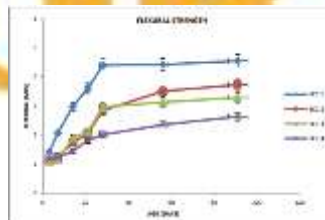
However, the correlation statistics presented in Table 4 indicate a strong positive relationship between the compressive strengths of the SCC mixes and the selected cement brands.

**Table 4: Correlation of the compressive strength of the selected brands**

	<b>SCC 1</b>	<b>SCC 2</b>	<b>SCC 3</b>	<b>SCC 4</b>
<b>SCC 1</b>	1	0.969433	0.979046	0.97127
<b>SCC 2</b>	0.969433	1	0.99692	0.968206
<b>SCC 3</b>	0.979046	0.99692	1	0.979291
<b>SCC 4</b>	0.97127	0.968206	0.979291	1

### Flexural Strength of the SCC Mixes

The flexural strength results of the SCC mixes are shown in Fig. 3. According to MCAAT (2009), concrete pavements function as simple, plain, non-reinforced concrete beams, and are classified as rigid due to their inherent beam strength, which enables them to span loads. Flexural strength is a critical parameter for calculating deflection in rigid pavement and plays a key role in the structural design of concrete pavements, as highlighted by Wright (1996).



**Fig. 3: Flexural strength of the selected brands at maturity**

Correspondingly, flexural strength of SCC 1 was the highest and this meet up with the standard specification for rigid pavement as specified by Wright (1996). The result of the flexural strength for SCC 1 also fell within the specified value for airfield rigid pavement according to FAA (2014) and European specifications for high quality JPCP which asserted that the flexural strength value should range from 4.3 to as high as 7.0 Mpa for all rigid pavement applications. SCC 2, 3 and 4 flexural strength was below pavement specification, however, the values are good enough for other structural applications as specified in BS 8110. Additionally, the correlation statistics indicated a strong positive relationship, suggesting that as the curing age increased, the flexural strength of the various SCC mixtures also increased.

**Table 5: Descriptive statistics of the flexural strength of the SCC**

Statistic	SCC 1	SCC 2	SCC 3	SCC 4
Mean	3.175	2.081667	2.193333	1.671667
Median	3.285	1.89	2.01	1.635
Maximum	4.61	3.5	3.9	2.35
Minimum	1.41	1.1	1.12	1.18
Std. Dev.	1.272348	0.931008	1.077732	0.465679
Skewness	-0.21601	0.479203	0.535288	0.288596
Kurtosis	1.616298	1.838567	2.010805	1.670139
Jarque-Bera	0.52532	0.566867	0.53116	0.52542
Probability	0.769003	0.753193	0.766761	0.768965
Sum	19.05	12.49	13.16	10.03

**Correlation of Flexural Strength for the Selected Brands**

Regression analysis of the compressive and flexural strengths at different ages revealed that the best fit for the data followed a logarithmic trend. Table 6 presents the correlation statistics, while Table 7 provides the equations governing the trend and the R<sup>2</sup> values, where y represents the flexural and compressive strengths and x represents the age.

**Table 6: Correlation**

	SCC 1	SCC 2	SCC 3	SCC 4
<b>BRAND A</b>	1	0.953066	0.939216	0.963215
<b>BRAND B</b>	0.953066	1	0.995969	0.986267
<b>BRAND C</b>	0.939216	0.995969	1	0.980307
<b>BRAND D</b>	0.963215	0.986267	0.980307	1

**Table 7: Regression equations**

MIX	REGRESSION EQUATION	R SQUARE VALUE
<b>FLEXURAL STRENGTH</b>		
SCC 1	$y=8.844\ln_{10}(x)+0.4846$	0.9211
SCC 2	$y=6.622\ln_{10}(x)+0.4497$	0.8758
SCC 3	$y=6.3604\ln_{10}(x)+0.7369$	0.9115
SCC 4	$y=4.4679\ln_{10}(x)+3.7296$	0.9772

COMPRESSIVE STRENGTH		
SCC 1	$y=10.149\ln[f_{0.1}](x)-1.3517$	0.8624
SCC 2	$y=6.9423\ln[f_{0.1}](x)+0.2068$	0.8831
SCC 3	$y=6.360\ln[f_{0.1}](x)+0.7369$	0.9115
SCC 4	$y=4.4679\ln[f_{0.1}](x)+3.7296$	0.9772

### Split Tensile Strength

Tensile properties have a direct impact on the initiation of transverse cracking and corner breaks in concrete. The tensile strength results for the SCC mixtures followed a similar trend to those observed in flexural and compressive strengths (Fig. 4). SCC 1 consistently exhibited the highest tensile strength throughout the curing period. A 30.5% difference in tensile strength was recorded between SCC 1 and SCC 2, which increased to 43.5% after 91 days of curing. As the curing age increased, the disparity in tensile strength between SCC 1 and the other mixtures became more pronounced. Model predictions regarding the relationship between tensile and compressive strength suggest that mix design parameters play a crucial role. However, since the concrete ingredients remained consistent throughout the research, with the only variable being the cement, it indicates that the brand and grade of cement significantly influence the tensile properties of SCC mixtures. This trend is also reflected in the results for compressive and flexural strengths.

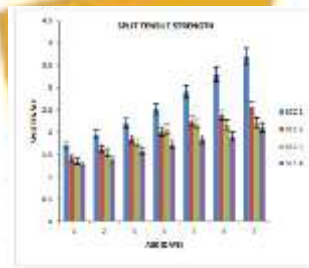


Fig. 4: Split tensile

### 4. Conclusion

This study thoroughly examined the performance of self-compacting concrete (SCC) using various brands of Portland limestone cement, focusing on rheological, compressive, flexural, and tensile strengths. The results highlighted that cement Brand A, with its higher calcium oxide content, provided superior compressive strength and favorable rheological properties compared to the other brands. This indicates that the chemical composition of cement, particularly the calcium oxide content, plays a crucial role in enhancing both the strength and workability of SCC. Rheological assessments showed that SCC 4 exhibited the best performance in terms of viscosity, segregation, and passing ability, aligning with EFNARC (2006) standards. In terms of compressive strength, SCC 1, made with Brand A, met the requirements for pavement construction at 28 days, demonstrating its suitability for rigid pavements. Similarly, SCC 1 also achieved the highest flexural strength, meeting the necessary specifications for structural applications. Additionally, SCC 1 consistently outperformed other mixes in tensile strength, which is vital

for resisting cracking and maintaining structural integrity. These findings underscore the significant impact of cement quality on the overall performance of SCC, with Brand A proving to be the most effective in achieving high strength and desirable properties for self-compacting concrete.

## 5. References

- [1] Momotaz, H., M.M. Rahman, M.R. Karim, Y. Zhuge, X. Ma, and P. Levett. "Changes in Flexural, Tensile and Impact Characteristics of Kerb Concrete Due to the Addition of Tyre-Derived Aggregates and Polypropylene Fibres." *J. Build. Eng.*, 2024, Article 108438.
- [2] Influence of Reclaimed Asphalt Pavement Aggregate on the Performance of Metakaolin-Based Geopolymer Concrete at Ambient and Elevated Temperatures." *Construction and Building Materials*, 2023.
- [3] Influence of Reclaimed Asphalt Pavement Aggregate on the Performance of Metakaolin-Based Geopolymer Concrete at Ambient and Elevated Temperatures." *Construction and Building Materials*, 2023.
- [4] "Effect of Waste Brick Powder Rich in  $\text{SiO}_2$  on the Physical and Mechanical Properties of Portland Cement Concrete Containing Coarse Recycled Asphalt Pavement Aggregates (RAP)." *Journal of Building Engineering*, 2023.
- [5] "A Systematic Review on Performance of Reclaimed Asphalt Pavement (RAP) as Sustainable Material in Rigid Pavement Construction: Current Status to Future Perspective." *Journal of Building Engineering*, 2023.
- [6] "Numerical Simulation of Effect of Reclaimed Asphalt Pavement on Damage Evolution Behavior of Self-Compacting Concrete under Compressive Loading." *Construction and Building Materials*, 2023.
- [7] Momotaz, H., Rahman, M., Karim, M., Zhuge, Y., Ma, X., and Levett, P. "Comparative Study on Properties of Kerb Concrete Made from Recycled Materials and Related Carbon Footprint." *Journal of Building Engineering*, vol. 72, 2023, Article 106484.
- [8] Momotaz, H., M. Rahman, M. Karim, Y. Zhuge, X. Ma, and P. Levett. "Properties of the Interfacial Transition Zone in Rubberised Concrete: An Investigation Using Nano-Indentation and EDS Analysis." *J. Build. Eng.*, 2023, Article 107405.
- [9] Wawrzencyk, J., A. Molendowska, and A. Klak. "Evaluation of the Causes of Concrete Kerbs Fast Damage." *IOP Conference Series: Materials Science and Engineering*, vol. 471, 2019, Article 032023.

IJORAR