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Investigating the Impact of Sika Admixtures on the Physico-Mechanical Properties of Concrete Formulated with Different Cement Types

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Abstract: This dissertation investigates the impact of Sika admixtures (Sikalite, Sikalatex, and Sikaviscocrete) on the physico-mechanical properties of concrete formulated with different types of cement, specifically Ordinary Portland Cement (Dangote 42.5) and Pozzolanic Cement (CIMAF 42.5). Despite the widespread use of Sika admixtures in concrete production, there remains limited understanding of their effects on concrete performance across various cement types. The overall objective of this study was to optimize concrete formulations to enhance strength and durability in diverse environmental conditions. The research employs the Dreux-Gorisse method for concrete mix design, targeting a compressive strength of 25 MPa. Laboratory tests assessed compressive strength, workability, density, and water absorption of concrete samples with varying percentages of three types of Sika admixtures: Sikalite, Sikalatex, and Sikaviscocrete. Key findings reveal that the incorporation of Sika admixtures significantly enhances concrete properties. For instance, 7-day compressive strength increased by 31% with Sikaviscocrete, achieving 23.1 MPa for Ordinary Portland Cement and 22.3 MPa for Pozzolanic Cement. Workability improved considerably, with an average slump of 49 mm for Sikaviscocrete compared to control mixes. Water absorption tests indicated a reduction of approximately 42%, underscoring enhanced durability. In conclusion, Sika admixtures effectively optimize concrete performance, making them particularly suitable for applications requiring high strength and durability. This study offers valuable insights for engineers aiming to improve concrete formulations through strategic use of chemical admixtures.

Keywords: Concrete, Sika Admixture, Compressive Strength, Cement Type, Workability.

INTRODUCTION

The investigation into the impact of Sika admixtures on the physico-mechanical properties of concrete formulated with different cement types is a critical area in advancing concrete technology. Concrete, primarily composed of cement, sand, gravel, and water, is the second most utilized substance worldwide after water, foundational in civil engineering applications such as beams, pillars, slabs, pavements, and retaining walls (Chowdy, 2023).

Physico-mechanical properties, particularly compressive strength, tensile strength, workability, and durability—are central to ensuring structural integrity and longevity (ACI 214R-11, 2011; Neville, 2011). Chemical admixtures, such as those from Sika, optimize these properties by modifying hydration and enhancing workability and strength without increasing water content (Alhozaimy et al., 2015; Mehta & Monteiro, 2014). However, limited understanding exists about how these admixtures interact with different cement types like Ordinary Portland Cement (OPC) and Pozzolanic Cement, leading to variable concrete performance (Kumar et al., 2018).

This study fills this gap by systematically evaluating how Sika admixtures influence concrete properties combined with different cement types, focusing on optimizing formulations to enhance strength and durability under varying environmental conditions. The research questions address the fundamental characteristics of concrete components, the required quantities for producing 1m^3 of concrete, and the effects of Sika admixtures on mechanical and physical properties. It employs the Dreux-Gorisse volumetric mix design method, emphasizing granular packing balance to optimize strength, workability, and durability, targeting 25 MPa compressive strength (Yousfi et al., 2014; Dreux & Festa, 1998). This method incorporates aggregate gradation, specific gravity, and moisture content to refine mix proportions, reducing cement paste requirements and improving mechanical performance (Lee et al., 2018).

Concrete exists in various forms tailored for specific applications, including ordinary concrete, self-compacting concrete (SCC), high performance concrete (HPC), fiber-reinforced concrete, fast hardening concrete, lightweight and heavy concretes, refractory concrete, reinforced concrete, and geopolymer concrete—each with unique properties shaped by materials and additives (Benamrane, 2017; Boukellouda, 2010). Cement types like OPC, Portland Pozzolana Cement (PPC), Sulphate Resisting Cement (SRC), Rapid Hardening Cement, White Cement, Low-Heat Cement, and Limestone Calcined Clay Cement (LC^3) influence concrete's mechanical and durability characteristics differently due to their unique physical and chemical compositions. For instance, PPC enhances long-term strength and durability through pozzolanic reactions, while SRC offers resistance against sulfate attack in harsh environments, and rapid hardening cement accelerates strength gain for expedited construction needs (Thomas, 2013; Mehta et al., 2014).

Sika admixtures include plasticizers, superplasticizers, water retainers, air-entrainers, setting accelerators, hardening accelerators, set retarders, and water repellents that modify both fresh and hardened concrete properties. They improve workability, reduce water demand, enhance strength development, and increase durability by reducing permeability and mitigating environmental damage (Alhozaimy et al., 2015; Mindess et al., 2003). Their interaction with cement and aggregates affects hydration kinetics and particle dispersion, influencing concrete microstructure and performance. For example, superplasticizers adsorb onto cement particle surfaces, promoting dispersion and reducing water content needed for hydration, thereby improving strength and workability simultaneously (Lehner et al., 2022; Siddique & Klaus, 2013).

Physico-mechanical properties, particularly compressive strength, tensile strength, flexural strength, workability, and durability, are key quality indicators. Compressive strength depends on mix design, curing, and admixtures (ACI 214R-11, 2011; Neville, 2011). Tensile and flexural strengths influence cracking resistance. Workability, defined by ease of mixing and placement without segregation, is enhanced by Sika admixtures without compromising strength. Durability is affected by cement type, admixture use, and exposure conditions, with admixtures reducing permeability and improving resistance to aggressive agents (Mehta et al., 2014; Kumar et al., 2018).

The study applies established testing standards (NF EN, ASTM) and mix design methodologies(Dreux-Gorisse)to analyze these interactions, aiming to provide practical guidelines for improved concrete formulations meeting modern civil engineering demands while considering environmental and economic aspects. The integration of admixtures technologies with diverse cement types promises enhanced Physico-mechanical properties, which are critical factors for sustainable infrastructure development (Mehta, 2001; Nguyen et al., 2022; Brown et al., 2020). This contributes insights bridging academic research and practical construction applications (Almeida et al., 2023; Lee & Lee, 2024).

MATERIALS AND METHODS

Source and Nature of Materials

Source of Materials

- **Cement:** Ordinary Portland Cement (Dangote 42.5) and Pozzolanic Cement (CIMAF 42.5) were used.
- **Aggregates:** The various aggregates with their diameters which were used for this research are shown in Table 1 below.

Aggregate Size (mm)	Characteristic	Source
0/5	Fine aggregate	Mbengwi Sand
5/15	Coarse aggregate	Dreamland Quarry
15/25	Coarse aggregate	Dreamland Quarry

- **Sika Admixtures:** Sikalite, Sikalatex, and Sikaviscocrete were used and were all gotten from the local market.

Nature of Materials

Before concrete formulation, the sand and gravel were identified by carrying out laboratory test on the samples. These tests included; sieve analysis, specific gravity, apparent density and sand equivalence test

- Sieve analysis was conducted following the norm NF P94 – 056. This test helps to give an idea of the gradation of the materials. The apparatus needed for this test include a set of sieves, scale balance, oven and a bowl.
- Sand equivalence test was conducted following the norm NF EN 933. This test is used to determine the cleanliness of the sand by the percentage of silty material in the sand. The apparatus needed for this test include a transparent measuring cylinder, an agitator tube, a measuring piston.
- Specific gravity test was done following the norm, NF P94 – 054, the value obtained from this test is used to obtain the proportion by mass for the aggregates after formulation. The apparatus needed for this test includes; a pycnometer, a thermometer, a scale balance.

- Apparent density test was done following the norm NF P18 – 558. The value obtained from this test is used to obtain the proportion by volume for the aggregates after formulation. The apparatus needed for this test include; a cylindrical mould, and a scale balance.

Experimental Protocol

Formulation Using Dreux-Gorisse Method

The concrete we formulated had as target strength after 28-days to be 25 Mpa

$$fcm \approx 1.2x25 = 30 \text{ MPa}$$

We used Dangote cement CEM II 42.5 (commercial strength class). The true class is estimated at F_{CE} = 51 MPa

The granularity of the gravel allows the estimation of the granular coefficient KDG with Dmax = 25 mm, and aggregates of average quality, K_{DG} ≈ 0.5. Table 3.2 below shows the various granular coefficients and the conditions under which they are chosen.

Table 2: Table of Granular coefficient

Quality of Aggregates	**Dimension D of Aggregates**		
	Fine (D≤16mm)	**Medium (25≤D≤40mm)**	**coarse (D≤63mm)**
EXCELLENT	0.55	0.60	0.65
GOOD	0.45	0.50	0.55
AVERAGE	0.35	0.40	0.45

The C/E ratio is evaluated with equation:

$$f_{cm} = K_{DG}.F_{CE}.(\frac{C}{E} - 0.5) \quad [1]$$

$$\frac{C}{E} = \frac{f_{cm}}{(K_{DG}.F_{CE})} + 0.5 \quad [2]$$

$$\frac{C}{E} = \frac{30}{(0.50x51)} + 0.5 = 1.68$$

The abacus makes it possible to estimate the quantity of cement required according to the C/E ratio estimated by formula above and the desired workability, which can be identified from the sag at the cone and desired in this application to 6cm.

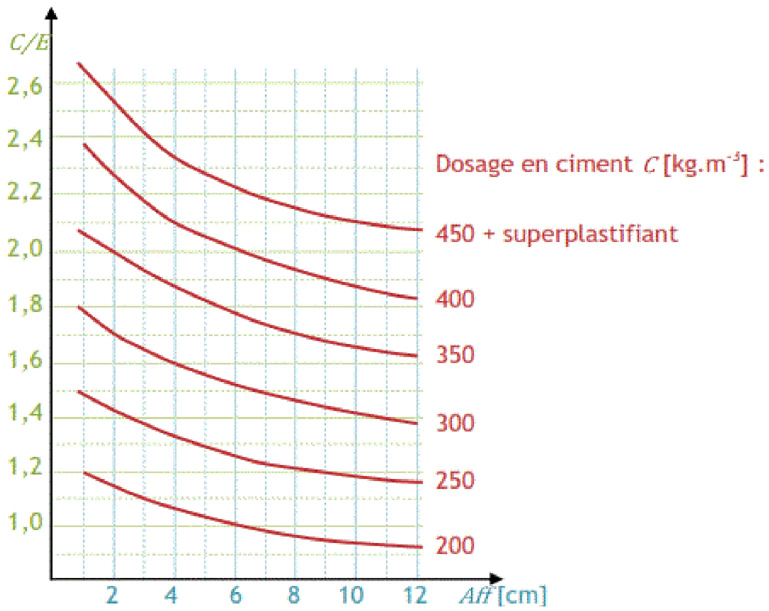

Figure 1: Chart for estimating amount of cement

The quantity of cement required C is estimated at 350 kg.m^3 of concrete.

We can therefore evaluate the quantity of water by substituting the quantity of cement obtained from the chart in the C/E formula

$$E = \frac{350}{(1.68)} = 208\ Kg$$

The correction is to be made to the water dosage if the maximum dimension of the aggregates is different from 25 mm.

In this application Dmax = 25 mm, the correction to be made is 0% on the water dosage E, i.e. 208 x1.00 = 208 L. m3.

The correction for water dosage is shown in Table 3 and the condition in which it is chosen.

Table 3: Table for correction of water dosage.

Maximum dimension of aggregates (Dmax)	5	10	16	25	40	63	100
Correction of dosage of water	+15	+9	+4	0	-4	-8	-12

This first part of the formulation of a concrete proposes for each of the constituents the quantities and their ratio:

C = 350 kg.m^3,

E = 208 L.m^3 and

C / E = 1.68.

However, concrete is made up of one sand and two gravels, the proportions of which still have to be determined.

Determination of the Quantity of Sand and Gravel

Reference granular curve: On the granulometric analysis graph, complying with standard NF-EN-933-1, a reference granular composition OAB is plotted. Point O is placed at the origin of the graph; point B corresponds to the dimension D_{max} of the largest aggregates at the ordinate 100%. The break point A is determined by:

- on the abscissa (from the dimension of the largest aggregates D_{max}) X_A:
- if $D_{max} \leq 20$ mm, the abscissa is D_{max} / 2;
- if $D_{max} > 20$ mm, the abscissa is located in the middle of the gravel segment limited by module 38 (5 mm) and the module corresponding to D_{max};
- On the y-axis: Y_A=50-$\sqrt{D_{max}} - K$ where K is a correcting term obtained from Table 4 below.

Table 4: Correction value

Vibration		Weak		Normal		Powerful	
Forms aggregates (sands in particular)		Rolled	Crushed	Rolled	Crushed	Rolled	Crushed
Dosage in Cement	400+Adjuvant.	- 2	0	-4	- 2	-6	-4
	400	0	+ 2	-2	0	-4	-2
	350	+ 2	+ 4	0	+ 2	-2	0
	300	+ 4	+ 6	+ 2	+ 4	0	+ 2
	250	+ 6	+ 8	+ 4	+ 6	+ 2	+ 4
	200	+ 8	+ 10	+ 6	+ 8	+ 4	+ 6

For our research, the aggregates were crushed; the power of the vibration was normal and the cement dosage C of 350. K is therefore taken as +2.

With the fineness modulus of 2.85 and the fact that the concrete is unpumped, do not result in any additional correction. Therefore, we have:

$$X_A = (5+Dmax)/2 = (5+25)/2 = 15 \qquad [3]$$

$$Y_A = 50-\sqrt{25} + 2 = 47 \text{ mm} \qquad [4]$$

That we report on the granular reference curve shown in Figure 2 below. It shows the variation in size of the aggregate and is used to obtain the percentage of aggregates required in the concrete mix.

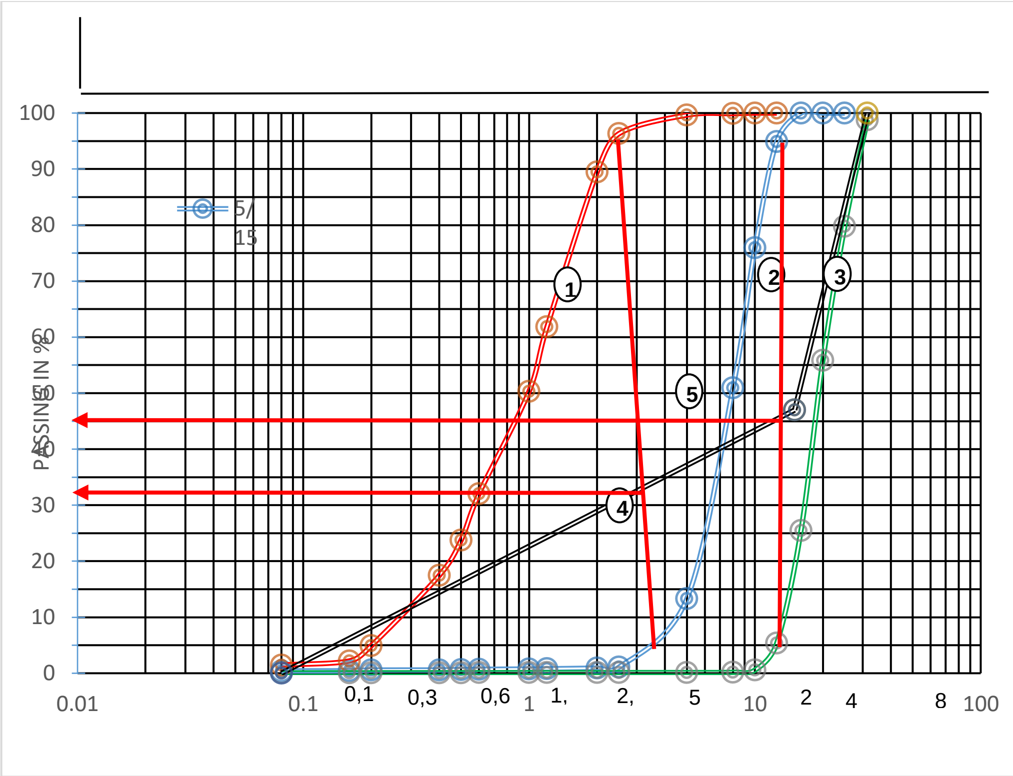

Figure 2: Reference granular curve

In this application, we are looking for a plastic consistency, the vibration is normal and D_{max}=25mm, therefore from the table above we could extract the compaction coefficient γ_{th} = 0.827. For 1m^3 of concrete and with γ_{th} = 0.827:

$$\gamma_{th} = \frac{V_{cement}+V_{aggregates}}{V_{concrete}} = \frac{V_{cement}+V_{aggregate}}{1} \quad [5]$$

$$V_{aggregates} = \gamma_{th} - V_{cement} = 0.827 - \frac{350[Kg]}{3{,}100[Kg.m^3]}$$

$$V_{aggregates} = 714L$$

Calculations of the Proportion of Aggregates per Meter Cube

Using the results curve (12% gravel 5/15, 55% gravel 15/25, 33% sand 0/5) it is possible to calculate the quantity of each of the constituents:

In Terms of Mass:

mass = total volume x aggregate % x specific weight [6]

$S_{0/5}$ = 0.714 x 0.33 x 2,754 = 648.9kg.m^3

$G_{5/15}$ = 0.714 x 0.12 x 2,980= 255.3kg.m^3

$G_{15/25}$ = 0.714 x 0.55 x 2,680 = 1052kg.m^3

In Terms of Volume

$$\text{Volume} = \text{total volume x aggregate \%} \quad [7]$$

$S_{0/5}$ = 0.714 x 0.33 = 235.62L

$G_{5/15}$ = 0.714 x 0.12 = 85.68L

$G_{15/25}$ = 0.714 x 0.55 = 392.70L

Calculation of Proportions to be Used to Fill the Casting Mould

The masses were reduced with respect to the volume of the mould used to cast the concrete cylinders.

$$V = \Pi \; x \left(\frac{D}{2}\right)^2 x \; H \text{ (for cylindrical moulds)} \quad [8]$$

Where,

- D = Internal Diameter of mould, 16 cm
- H = Height of mould, 32cm
- Volume of mould = 0.0064 m3

$S_{0/5}$ = 648.9 x 0.0064 = 4.15 kg

$G_{5/15}$ = 255.3 x 0.0064 = 1.63 kg

$G_{15/25}$ = 1052 x 0.0064 = 6.73 kg

Admixture Dosage by Cement Weight

a) Sikalite; 5%
b) Sikalatex; 2%
c) Sikavicocrete; 2%

Slump Test (NF EN 12350-2)

Apparatus; Slump cone and base, Compacting rod, ruler.

Test Procedure:

This test was done by filling concrete into the Abrams cone in 3 layers. Every layer was compacted by 25 strokes of a tamping rod. When the mould was filled, it was carefully removed and the depth of depression was measured as the slump value.

Casting of Concrete Cylinders (NF EN 12350-1)

Apparatus; Cylindrical mould (15x30 cm, 16x32cm), Scale balance, Calibrated measuring cylinder, Engine oil and brush, Spade, Compacting rod.

Test Procedure:

After the slump test was conducted, the concrete was then filled into the already oiled moulds in 3 layers and giving 25 strokes of the tamping rod to each layer. The moulds were then allowed undisturbed for 24 hours and some for 48 hours, after which the samples were demolded and kept in a water bath for curing.

Compressive Strength Test (NF P94-077)

The compressive strength test was done using the HUMBOlDT compression machine (HCM – 4000IHAC.XX, manual 400,000 Ibs/1,780 KN). The crushing machine uses the principles of action and reaction. The machine exerts a force on the surface area of the element and the force at which the elements starts to fail is the maximum force which the element can carry. The machine displays the maximum force exerted and the corresponding strength of concrete in MPa.

On the day of crushing, the concrete samples were removed from the water bath and placed under the sun for the water on its surface to get dry. After that the concrete sample was then weighed. The weight was then used to calculate the density of the concrete after immersion in water. After weighing the concrete sample, it was taken to the Sulphur room where a mixture of Sulphur and egg shells was used to smoothen the surface of the concrete sample. The essence of this process was to ensure that during crushing the force which is applied on the surface of the concrete element is evenly distributed throughout the element. The concrete element was then taken for crushing

RESULTS AND DISCUSSION

Results

Results for Formulation

Dreux Gorrise method of formulation was used to obtain the proportions of the various components of concrete. Concrete formulated was done at a batching dosage of 350Kg/m^3 giving a 28-day strength of 25 MPa, a slump value of 6 cm and cement water ratio of 1.68. Table 5 below presents the proportions of the components in terms of mass and volume.

Table 5: Proportion of concrete components

Component	Proportion %	Specific gravity	Absolute density	Absolute volume l/m3	Specific weight kg(m3)	Apparent volume(l/m3)	Dosage per 1 bag of cement	Dosage per 60L wheel barrow/Bag of cement
0/5	33	2.754	1.445	235.6	649	449.1	93	1.07
5/15	12	2.98	1.453	85.7	255	175.7	36	0.42
15/25	55	2.68	1.399	392.7	1052	752.3	150	1.79
DANGOTE /CIMAF				113	350	350	50	1 bag
Water				208	208	208	30	29

Source: Excel 2017

Table 6: Admixture Dosage (by cement weight)

Sika Admixture	Typical dosage(% by cement weight)	Dosage used (% by cement weight)	Application Note
Sikalite	1-2%	2%	Add as powder to dry components. Dry mix befor adding water
Sikalatex	5-10%	5%	Predilute with water. Add to wet mix with part of mixing water
Sikaviscocrete	0.5-2%	2%	Add as liquid to wet mix, preferably with remaining mixing water

Results of Weight and Density of Concrete Samples

After the samples were removed from the water bath and kept for the surface water to drain off, the samples were weighed before being crushed. From the weight, the density of the concrete samples was obtained. Table 7 below presents the weight and density of the concrete samples after being cured for 7 and 28 days.

Table 7: Density of concrete cylinders at 7and 28days.

Sample Type	Initial Dry Weight (kg)	Density After 7 Days (kg/m^3)	Density After 28 Days (kg/m^3)
DANGOTE			
Control Sample	15.24	2450	2500
Sikalite	15.30	2460	2510
Sikalatex	15.46	2470	2520
Sikaviscocrete	15.58	2485	2530
CIMAF			
Control Sample	15.22	2445	2495
Sikalite	15.36	2455	2505
Sikalatex	15.46	2465	2515
Sikaviscocrete	15.66	2480	2535

Results of Water Absorption

The water absorption percentages that were obtained at 7 and 28 days are shown in Table 4.12 below:

Table 8: Water absorption of concrete cylinders at 7and 28days

Sample Type	Dry Weight (kg)	Wet Weight After 7 Days (kg)	Water Absorption (%) After 7 Days	Wet Weight After 28 Days (kg)	Water Absorption (%) After 28 Days
DANGOTE					

Control Sample	15.24	15.74	3.28	15.84	3.93
Sikalite	15.30	15.80	3.26	15.90	3.92
Sikalatex	15.46	15.96	3.24	16.06	3.89
Sikaviscocrete	15.58	16.08	3.22	16.18	3.84
CIMAF					
Control Sample	15.22	15.72	3.29	15.82	3.95
Sikalite	15.36	15.86	3.26	15.96	3.91
Sikalatex	15.46	15.96	3.25	16.06	3.88
Sikaviscocrete	15.66	16.16	3.20	16.26	3.83

Concrete Compression Test Results

Table 9: Compressive strength test results

Sample Type	**Compressive Strength (MPa) After 7 Days**	**Compressive Strength (MPa) After 28 Days**
DANGOTE		
Control Sample	20.5	30.0
Sikalite	21.0	31.5
Sikalatex	22.0	32.0
Sikaviscocrete	23.0	33.5
CIMAF		
Control Sample	19.5	29.0
Sikalite	20.0	30.0
Sikalatex	21.5	31.0
Sikaviscocrete	22.5	32.5

Tensile Test Results

The split tensile strengths obtained for 7 and 28 days is shown in Table 9 below;

Table 10: Tensile strength test results

Sample Type	**Tensile Strength (MPa) After 7 Days**	**Tensile Strength (MPa) After 28 Days**
DANGOTE		
Control Sample	2.5	3.5
Sikalite	2.7	3.7
Sikalatex	2.9	4.0
Sikaviscocrete	3.1	4.2
CIMAF		
Control Sample	2.4	3.4

Sikalite	2.6	3.6
Sikalatex	2.8	3.8
Sikaviscocrete	3.0	4.1

Graphs were plotted to demonstrate the variation in properties with respect to the different admixture and cement types used. The response of each physico-mechanical property to the varying admixtures and cement types in concrete is shown in Figures 3 to 6 below

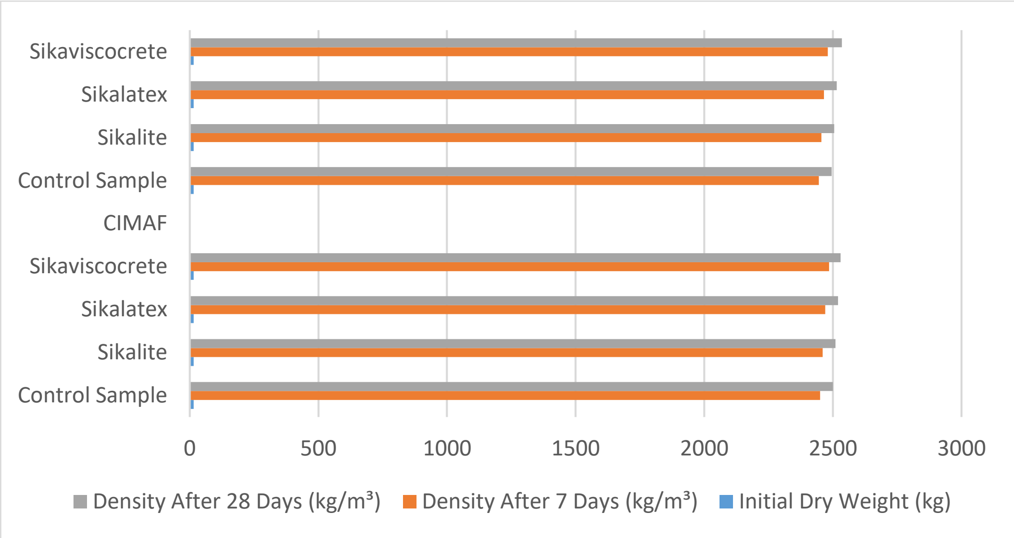

Figure 3: Density Test Results

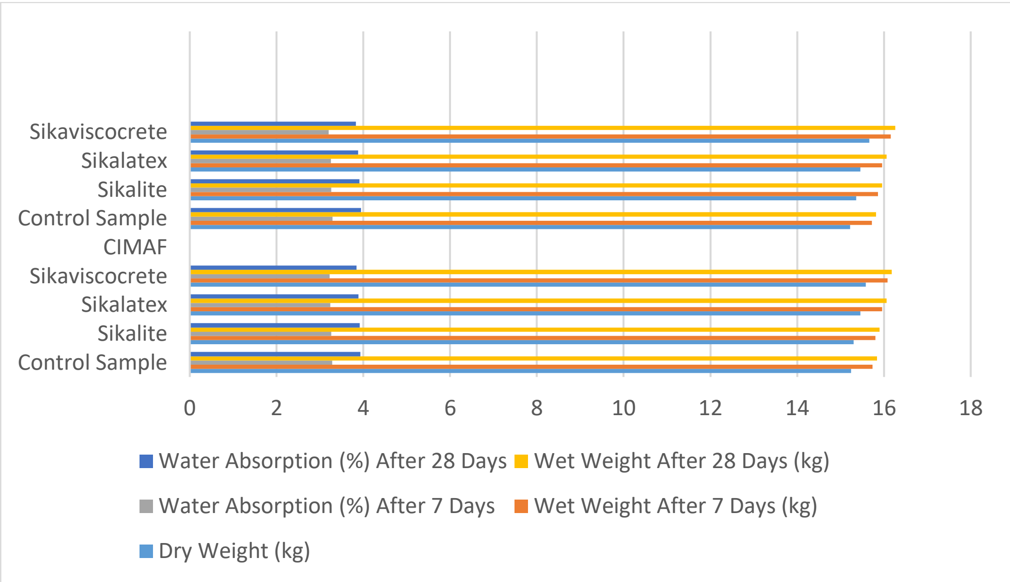

Figure 4: Water Absorption Test Results

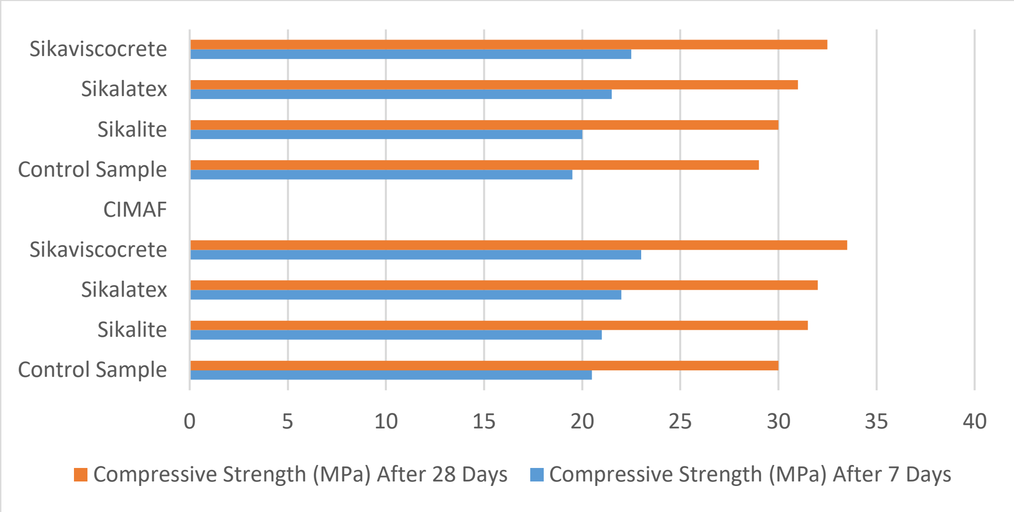

Figure 5: **Concrete Compression test results**

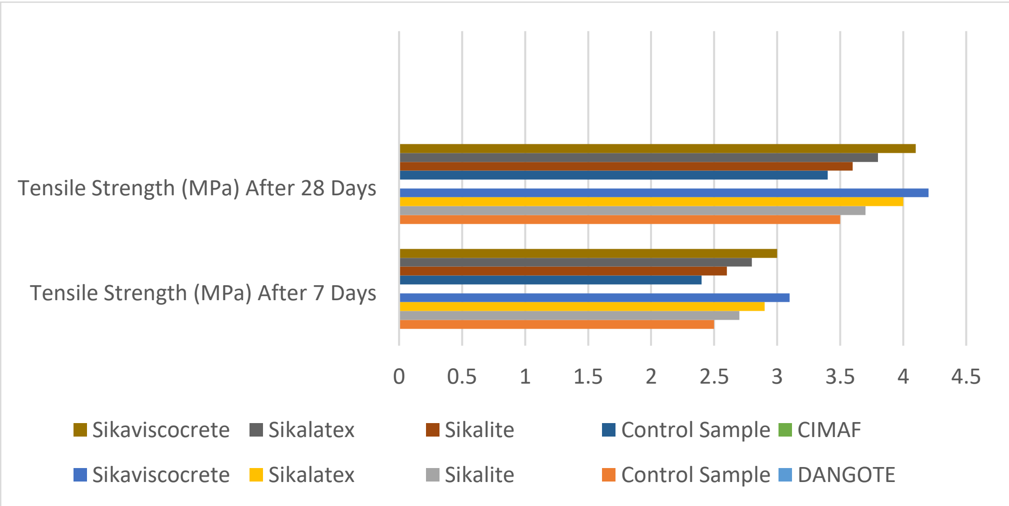

Figure 6: **Tensile Test Results**

Discussion

The investigation into the effects of Sika admixtures on the physico-mechanical properties of concrete formulated with various cement types yielded significant insights. Sieve analysis verified aggregates met NF gradation standards and quality (Norme Francaise et Europeennes, 1996), indicating their suitability for concrete production. Specific gravity and apparent density tests confirmed good-quality aggregates (Norme Francaise et Europeennes, 1981, 1991). Results indicated that the incorporation of Sika admixtures, particularly Sikaviscocrete, led to notable enhancements in workability, as evidenced by increased slump values. This improvement facilitates easier placement and compaction, which are critical for structural integrity. The density measurements taken after 7 and 28 days of curing showed a consistent increase with the addition of Sika admixtures, reinforcing the notion that these admixtures enhance the packing efficiency of the concrete mix. Additionally, the water absorption tests revealed a significant reduction in permeability with the use of Sika admixtures, particularly Sikaviscocrete, indicating improved durability against environmental factors. The compressive strength tests demonstrated that Sika admixtures significantly improved strength, with Sikaviscocrete yielding the highest values at both 7 and 28 days. Similar trends were observed in tensile and flexural strength tests, highlighting the versatility and effectiveness of Sika admixtures in enhancing the mechanical properties of concrete. Overall, the results clearly indicate that using Sika admixtures can optimize concrete formulations, making them advantageous for various applications, particularly in challenging environmental conditions. (Alhozaimy et al., 2015; Mindess et al., 2003; Siddique & Klaus, 2013). These results align with previous studies on admixture effects on concrete microstructure and strength (Mehta & Monteiro, 2014; Lehner et al., 2022).

Conclusions and Recommendations

The research concluded that Sika admixtures enhance physico-mechanical properties of concrete formulated with various cement types, especially Sikaviscocrete (Alhozaimy et al., 2015). The study determined that the aggregates used were well-graded, which is vital for achieving the desired mechanical properties. The admixtures were found to improve workability, reduce water absorption, and increase strength—particularly with Sikaviscocrete, which consistently demonstrated superior performance in all measured properties. It was noted that Pozzolana cement (CIMAF 42.5) exhibited lower absolute strength values and higher water absorption compared to Ordinary Portland Cement (Dangote 42.5), yet still showed notable improvements when Sika admixtures were used. Based on these findings, several recommendations were proposed. First, it is advisable to use Sikalatex or Sikalite in conditions where extended setting times are advantageous, such as in hot climates or when transporting concrete over long distances(Lee & Lee, 2024). Second, on-site monitoring of water absorption and strength development is crucial to ensure performance targets are met, particularly with locally sourced Pozzolana cements. Future research should investigate the effects of additional types of Sika admixtures across a wider range of cement types to gain a more comprehensive understanding of their impacts. Long-term studies are also recommended to assess the durability and performance of concrete containing various admixtures in different environmental conditions. Lastly, promoting educational programs to disseminate knowledge about the benefits and applications of Sika admixtures can facilitate their widespread adoption in the construction industry, ultimately leading to more sustainable and durable concrete solutions. This comprehensive approach will not only enhance material performance but also address critical ecological concerns in construction practices.

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Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, [Mbuh Moses Kuma], upon reasonable request.

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