ORIGINALE ARTICLE

EVALUATING THE INFLUENCE OF SELECTED CONCRETE ADMIXTURES ON THE PHYSICAL, CHEMICAL AND MECHANICAL PROPERTIES OF PASTE AND MORTAR SAMPLES CURED UNDER CAMEROONIAN CLIMATE CONDITIONS

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ABSTRACT

Introduction: The main objective of this research work is to conduct a comparative study investigating the effects of admixtures on the physical and mechanical properties of concrete. In order to achieve this objective, the research utilized the Dreux Gorisse method to calculate the quantities of different components of fresh concrete for each concrete formulation described in the study. **Objective**: The objective of this research is to compare the influence of admixtures on the physical and mechanical properties of concrete. To achieve this, the study employed the Dreux Gorisse method to determine the component quantities for each concrete formulation. **Methods**: The research conducted mixing experiments in a laboratory using a concrete mixer. The quantities of various components for both admixture-free and admixture-added cases were determined based on the corresponding quantity of cement. Fresh concretes were obtained from cylindrical molds, and the slump of a portion of the fresh concretes was measured using the Abrams cone. The hardened cylindrical concretes were then demolded and immersed in water for subsequent compression tests at 7 and 28 days of age. These compression tests provided data on the characteristic resistance of each type of concrete. Additionally, detailed observations were made to gain a better understanding of the significance of the admixture as a water reducer. **Results**: The compression tests conducted on the hardened cylindrical concretes provided data on the characteristic resistance of each type of concrete. The results of these tests revealed significant variations in the physical and mechanical properties of concrete with and without admixtures. Through the observations made during the study, a clear understanding of the importance of admixtures as water reducers was gained. **Conclusion**: The comparative study on the effects of admixtures on the physical and mechanical properties of concrete yielded valuable insights. The research findings demonstrated that the inclusion of admixtures in concrete formulations had a noticeable impact on its performance. The use of admixtures as water reducers proved to be effective in enhancing the desired properties of concrete. Therefore, it is recommended to consider the inclusion of suitable admixtures in concrete mixtures to optimize their physical and mechanical characteristics. These findings contribute to advancing the knowledge and understanding of concrete technology and can be valuable for the construction industry in achieving better quality and performance of concrete structures.

***Keywords**: Comparative study; Concrete; Physical and mechanical properties; Admixture.*

1. INTRODUCTION

Concrete has been extensively researched by numerous authors [1,2]. Its utilization dates back to 1850, and its production relies on readily available natural resources found worldwide [3]. Concrete's workability allows for easy handling, making it suitable for large-scale projects such as bridges and high-rise structures [4]. Over the past century, concrete has undergone significant development, evolving from traditional compositions consisting of four basic components (cement, water, sand, and gravel) to complex formulations that incorporate admixtures [5]. Admixtures are chemical substances added during concrete mixing in specific proportions (by mass of cement) to modify the properties of the mixture in both its fresh and hardened states.

Since the 1980s, advancements in concrete formulation have led to the introduction of various specialized concretes that cater to specific requirements, such as self-compacting and high-performance concretes [6]. These developments have emerged in response to the growing demands of urban construction projects, resulting in a wide range of concrete formulations used in construction and public works [7]. As one of the most commonly used construction materials, concrete's performance continues to improve, particularly in terms of mechanical strength and durability [8]. Consequently, formulating concrete involves selecting specific properties based on desired outcomes. While ordinary concrete typically comprises gravel, sand, cement, and water, researchers and users have introduced new product formulations, including admixtures, to achieve unique properties [5].

Given the worldwide importance and utilization of concrete, both with and without admixtures, numerous studies have demonstrated that the use of admixtures can have positive or negative effects on the physical and mechanical properties of concrete, depending on their intended roles and applications. Admixtures facilitate better flow and compaction, particularly around reinforcements [9]. Therefore, it becomes essential to examine the influence of different superplasticizing admixtures available on the Cameroonian market on the physical and mechanical properties of concrete. However, previous research has not adequately considered recent developments in both ordinary and admixture-enhanced concrete [1]. Recent cases have unveiled certain limitations, prompting the need for a comprehensive understanding of the influence of admixtures on the physico-mechanical properties of concrete. Drawing on existing literature and the latest advancements in concrete formulations, this study aims to address the following questions:

- Do super water-reducing plasticizers available in the Cameroonian market enhance the performance of concrete?
- Do these admixtures increase the compressive strength of concrete?
- Do these admixtures improve the physical properties of concrete?

The primary objective of this research is to conduct a comparative study on the impact of admixtures available in the Cameroonian market on the physico-mechanical properties of concrete. To achieve this, we utilized several types of chemical admixtures, including super water-reducing plasticizers such as Sika Viscoflont-28, Sika Viscocrete Krono-20HE, and Master Glenium 26.

2. MATERIALS AND METHODS

2.1 Cement

The cement used to make concrete is "Robust" of CIMENCAM (CPJ 35 type) which is a Portland cement with addition (pozzolan or limestone). Its resistance class is 42.5. Its normative name is CEM II B-P 42.5R. Its setting time is more than 60 minutes, with an average resistance at 2 days of 20Mpa and at 28 days of 62.5 MPA [10, 11].

2. 2 Aggregates

2. 2.1 Sand

The sand used must comply with standard EN 196-1 with an apparent density of 2600 $\mathrm{kg/m^3}$. The sand used is river sand from Moungo, with the particle size analysis, which is given Table A1 in the appendix A1, allowing us to plot the curve of Fig.1 and to calculate the uniformity coefficient:

$$C_u = \frac{D60}{D10} = \frac{0{,}685}{0{,}315} = 2{,}17 > 2 \qquad (1)$$

Hence our natural sand to be used is of a spread grain size.

The curvature coefficient:

$$C_c = D30^2/(D10 \times D60) = 0{,}315^2/\ (0{,}315 \times 0.125) = 0{,}50 < 3 \qquad (2)$$

Natural sand is poorly graded.

Let's determine the fineness modulus:

$$\begin{aligned} FM &= \frac{1}{100}\sum cumulatuve\ refusal\%\ \text{sieves}\{0{,}160;\ 0{,}315;\ 0{,}63;\ 1{,}25;\ 2{,}5;\ 5\} \\ &= \frac{1}{100} \times 258,\ 1 = 2{,}581. \end{aligned} \qquad (3)$$

A finesse modulus, Fm = 2,581, thus 2.2 ≤ 2,581≤ 2.8, we are in the presence of sand that is predominantly fine-grained.

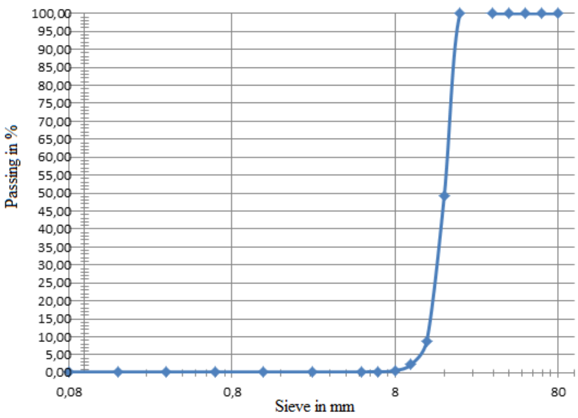

Figure 1: Curve of the granulometric analysis results of river sand 0/5.

2.2.2 Gravel

In this context, we employ 2 varieties of gravel, namely 15/25 and 5/15, sourced from the Logbadjeck quarry. The grain size analyses can be referenced in Figures 2 and 3.

2.2.2.1 Gravel particle size 15/25

The graph below illustrates the results of Table A2 of appendix of the particle size analysis of 15/25 aggregates.

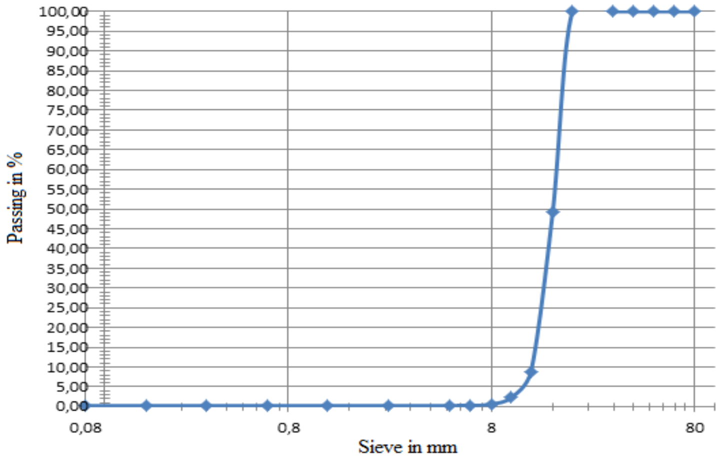

Figure 2: Representative curve of the particle size analysis results of 15/25 gravel

The loss found is:

$$P = \frac{M0-MT}{M0} \times 100 = \frac{8436-8415}{8436} \times 100 = 0{,}249\%, \quad (4)$$

$$C_u = \frac{D60}{D10} = 2{,}28. \quad (5)$$

Our gravel to use is of a spread grain size:

- Curvature coefficient :

$$C_c = D30^2/(D10 \times D60) = 12{,}5^2/\ (12{,}5\times16) = 0{,}78, \quad (6)$$

our gravel is poorly graded.

2.2.2.2 Gravel particle size 5/15

The graph below illustrates the results of appendix 3 of the particle size analysis of 5/15 aggregates.

The loss,

$$P = \frac{M0-MT}{M0} \times 100 = \frac{1516-1515{,}3}{1516} \times 100 = 0.046\% \quad (7)$$

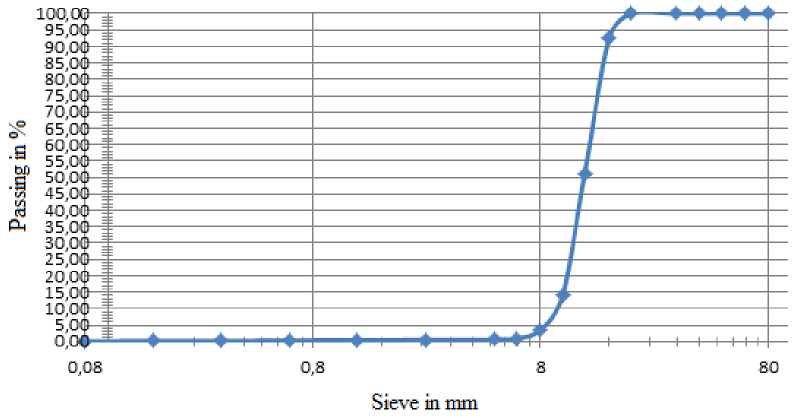

Figure 3: Representative curve of the particle size analysis results of gravel 5/15.

- Uniformity coefficient: $C_u = \frac{D60}{D10} = 2.56$, thus, our gravel has a spread grain size.

- Curvature coefficient:

$$C_c = D30^2/(D10 \times D60) = 10^2/(8\times 12.5) = 1.6, \quad (8)$$

Thus, our gravel is well graded.

2.3 Admixtures:

The admixtures utilized in formulating our concrete consist of superplasticizers obtained from Sika Cameroon, an admixture production company located at the autonomous port of Douala.

Admixtures are chemical substances that, when incorporated in small quantities (less than 5% of the weight of cement), enhance certain properties of concrete in both its fresh and hardened states. In our research, we will employ three (03) distinct types of superplasticizer admixtures. The characteristics of these admixtures are presented in the following table:

Table: Characteristics of the Additives used.

Admixture	Trade name	Shape	Dosage	Density (g/ml at 20°C)
Super plasticizer, high reducer Water for concrete, High performance and very long workability retention.	Mastre Glenium 26	Viscous liquid	0.3% to 2% of the weight of the cement,	1.08±0.02 g/cm^3
Super plasticizer, high water reducer, high performance and very long maintenance of workability, constant consistency and fluidity of the concrete	Sika viscoflow28	Viscous liquid	0.3% to 1.4% of the weight of the cement,	1.03±0.02 g/cm^3
Super plasticizer, high water reducer for self-placing concrete farms made with or without normalizing addition; concrete with a low C/W ratio very high initial strength; neat facing; improvement of sustainability by reducing the C/W ratio; making self-placing concrete and eliminating vibration	Sika viscocrete 20he	Viscous liquid	0.1% to 5% of the weight of the cement	1.085±0.020 g/cm^3

2.4 Formulation of admixtureed and unadmixtureed concrete

The formulation method used makes it possible to establish the expression of the mass of the aggregates according to the dosage of cement and water to be used, which is based on the Dreux Gorisse method [11]. This method makes it possible to determine, based on the workability and resistance criteria defined by the specifications, the nature and quantities of materials necessary to make a cubic meter of concrete (water E, cement C, sand g and gravel G in kg/m^3).

Several successive calculation steps are necessary to obtain the theoretical concrete formulation, namely: Determination of the C/W ratio, determination of C and W, determination of the optimal mixture with minimum void, determination of compactness of concrete and determination of the mass of aggregates

2.5 Test protocols

This section presents more explicitly some tests carried out during this work.

2.5.1 Tests on materials

The sand equivalent, particle size analysis of river sand with a diameter of 0/5, grain size analysis of gravel with diameters of 5/15 and 15/25, as well as measurements of the flattening coefficient, apparent density, and weight specificity, were carried out as outlined in reference [13].

2.2.2-Preparation of concrete specimens:

- Mixing

The components are sequentially introduced into the mixer in the following order: sand, cement, and gravel. Dry mixing is performed for one minute, after which water is added while the mixture continues for an additional two minutes. Subsequent to the water addition, the mixing process persists for a few more minutes.

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Figure 4: Mixing. (left): dry; (right): wet.

- Placing concrete

Before filling, the inner surface of the mold should be coated with a thin film of oil preventing the concrete from adhering to the mold. The cylindrical mold of diameter 16cm and height 32cm is filled with fresh concrete in three almost equal layers. For each layer, the tightening of the concrete must be carried out immediately using a vibrating needle.

- Conservation of test pieces

According to the provisions of standard EN 12390-2, it is required that the specimens remain in the mold and be safeguarded against shocks, vibrations, and drying for a minimum of 16 hours and a maximum of 3 days, at a temperature of 25°C ±5°C. Subsequently, after demolding, the test specimens should be stored in water until the time of testing, maintaining a temperature of 20°C ±2°C. Please refer to Figure A1 in the appendix for further clarification.

2.5.3 Tests on fresh concrete

This test is undoubtedly one of the simplest and most frequently used, because it is very easy to implement. The slump at the Abram's cone of the fresh concrete is determined for each batch [11].

2.5.4Tests on hardened concrete

Equipment used:

-An ELE International brand compression testing machine of 1bf ×100 kN.
-Surfacing device. The compressive strength is given by the following equation:

$$f_{cj} = F/Ac, \tag{9}$$

where:
f_{cj} expressed in mega pascal Mpa;
F is the maximum load and Ac is the area of the section of the specimen to which the compressive force is applied, calculated from specimen measurements. Compressive strength must be expressed to the nearest 0.1 MPa.

3. RESULTS AND DISCUSSION

This section will focus on the results, discussion and interpretation of the results of experimental tests on these concretes, namely the compressive strength test and the slump test.

3.1 Sand equivalent test

Table 3: Results of sand equivalent test on river sand used according to standard NF EN 933-8.

	Specimen 1	**Specimen 2**
Total height of sand h_1 (cm)	10,8	10,6
Height of sand at rest h_2 (cm)	10,5	10,3
Sand equivalent per test tube	95,5 %	94,5%
Total sand equivalent	95.00%	

- ES≥80: The presence of very clean sand, devoid of clay fines, poses a potential issue as it may result in insufficient plasticity in the concrete mixture.

- Following calculations based on sand equivalent tests, an average ES value of 95.00% is obtained, indicating that the natural sand is exceptionally clean but lacks clay fines. This absence of fines poses a risk of compromising the desired workability of our concrete. Consequently, increasing the water dosage becomes necessary to achieve concretes with exceptional strength despite the potential reduction in plasticity.

3.2 Concrete slump and C/W ratio

Slump measurements were taken at the Abrams cone to assess the workability of the concrete, the results of which can be found in the table below.

Table 4: Concrete slump and C/W ratio.

	Ordinary concrete	**Admixture Master Glenium R 26**	**Admixture Sika viscoflow-28**	**Admixture Sika viscocrete 20He**
C/W	1,54	1,54	1,54	1,54
Slump of mixture 1	8.00cm	9.00 cm	8.00cm	8.00cm
Slump of mixture 2	8.00cm	8.00cm	8.00cm	7.00cm
Average of slump	8.00cm	8,5cm	8.00cm	7,5cm

Let us outline that the results of this test emphasize that the subsidence is decadent, but despite this decadence, the concrete obtained is plastic.

- The slump of the concrete based on 1.4% of Master Glenium 26 admixtures is equal to 8.5 cm;
- The slump of the concrete based on 1.4% of Sika viscoflow-28 admixtures is equal to 8.0cm;
- The slump of the concrete based on 1.4% of Sika viscocrete 20He admixtures is equal to 7.5cm.

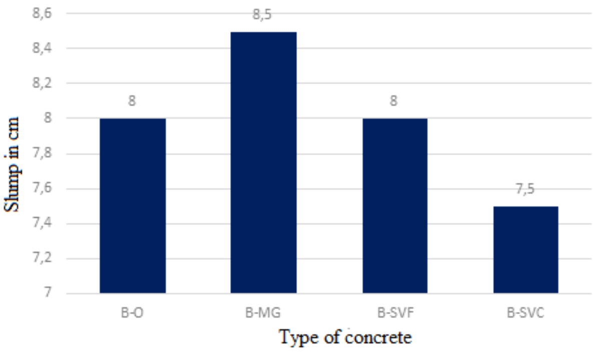

Figure 5: Abram's cone slump test depending on the types of concrete

As presented in the figure 5, it can be observed that the slump remains consistent for both ordinary concrete and viscoflow-28 concrete, depending on the desired workability. However, a decline can be observed in the case of master glenium-26 concrete, which exhibits a relatively more fluid behavior compared to the other concretes. On the contrary, sika viscocrete-20HE concrete demonstrates a firmer behavior compared to the others, despite having the same water dosage.

3.3 Test to determine the density of hardened concrete

The graph of Fig.6 illustrates the results to determine the density of hardened concrete.

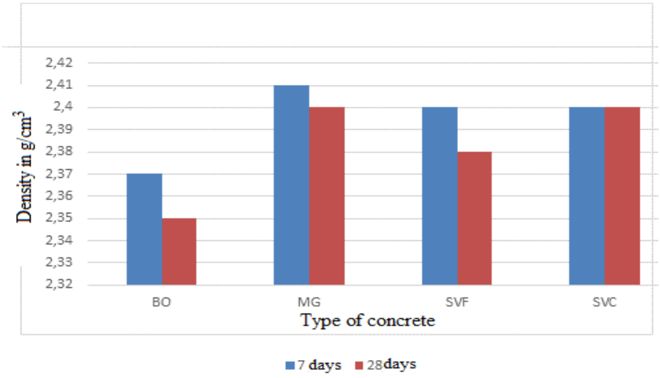

Figure 6: Test to determine the density of hardened concrete depending on the types of concrete.

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Based on the graph, the findings indicate a decrease in density when comparing the admixed concretes to ordinary concrete. Interestingly, the master glenium-26 concrete exhibits a higher density than the other two admixed concretes. It is worth noting that this specific admixture, dosed at 1.4% as per the technical specifications provided, exhibits secondary characteristics. In addition to its superplasticizing properties, it also demonstrates a setting retarder behavior, resulting in a longer hardening time. Consequently, after the hardening process, the master glenium-26 concrete displays a higher density compared to the other two concretes.

3.4 Compression test

The graph below illustrates the results of the compression test appendix.

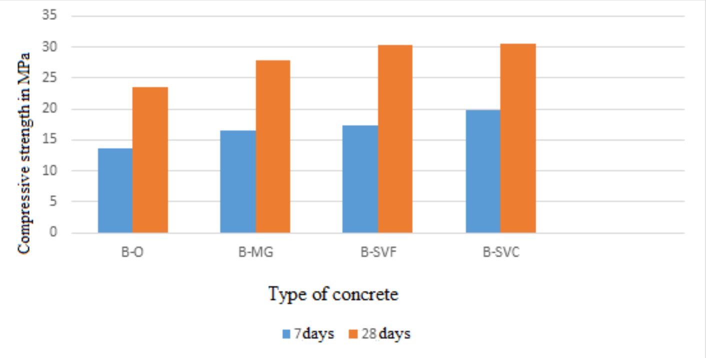

Figure 7: Compression test depending on crushing days.

The mean compressive strength of non-admixed concrete, determined seven days after formulation, is 13.01 MPa with a slump of 8.00 cm. The average compressive strength at 28 days reaches 24.37 MPa, indicating a lower resistance compared to concrete with admixtures. Upon calculating the standard deviation for various test specimens, it is evident that ordinary concrete, Master Glenium concrete, and viscocrete concrete exhibit a dispersion pattern around their respective averages. In contrast, Sika viscoflow-28 concrete demonstrates a denser and less resistant dispersion pattern. This observation underscores the impact of the admixture, a water-reducing fluidizer, incorporated during the mixing process, inducing alterations in concrete properties and enhancing its performance. Furthermore, the addition of this admixture is associated with an observable increase in concrete strength.

3.5 Absorption test

The graph of Fig.8 illustrates the results of the water absorption test appendix.

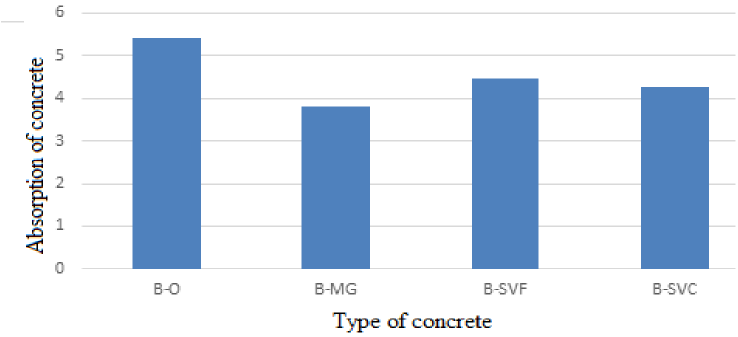

Figure 8: Water absorption test of specimens depending on the types of concrete at 28 days.

The test results reveal that on the 28th day of compressive testing on the specimens, water absorption decreases. This decline is attributed to the fact that concrete with admixtures exhibits lower water absorption compared to ordinary concrete. Specifically, Master Glenium-26 displays even lower water absorption than the other two admixtures, signifying that ordinary concrete is more porous, while Master Glenium-26 is less absorbent than the other two concrete compositions.

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Table 3: The strength of concrete at 7 and 28 days. A: without Admixture, MG: with Master Glenium Admixture, SVF: with Sika Viscoflow 28, SVC: with Sika Viscocrete 20He.

Days	Admixtures	No. Sample	Masses (g)	Apparent density	Resistance to simple understandings		Average (Mpa)	Standard deviation
					Total load (F in kN)	Stress F/AC (Mpa)		
7 days	A	1	15364	2,38	320	13,92	13.01	0,76
		2	15258	2,37	245	12,19		
		3	15286	2,37	260	12,93		
	MG	1	15509	2,41	330	16,42	16,51	0,54
		2	15648	2,43	325	16,17		
		3	15456	2,40	340	16,96		
	SVF	1	15570	2,42	375	18,66	17,24	1,14
		2	15320	2,38	325	16,17		
		3	15356	2,38	340	16,91		
	SVC	1	15576	2,42	385	19,15	19,90	0,61
		2	15435	2,40	400	19,90		
		3	15488	2,40	415	20,65		
28 days	A	1	15126	2,35	475	23,63	24,37	0,29
		2	15114	2,35	500	24,88		
		3	15110	2,34	480	23,88		
	MG	1	15281	2,37	570	28,36	27,28	0,87
		2	15614	2,42	515	26,62		
		3	15488	2,40	540	26,87		
	SVF	1	15344	2,38	630	31,34	30,26	1,58
		2	15347	2,38	580	31,34		
		3	15457	2,40	565	28,11		
	SVC	1	15438	2,40	590	29,35	30,51	1,2
		2	15400	2,39	610	30,35		
		3	15443	2,40	640	31,85		

Table 4: Water absorption of different concretes at 28 days.

Type of concrete	**A**	**SVF**	**MG**	**SVC**
Absorption rate	5.43	4.48	3.82	4.26

4. CONCLUSION

In conclusion, the comparative analysis of concrete performance, incorporating three Cameroonian market-available admixtures, focused on physico-mechanical properties. The summary of studies on Master Glenium 26, Sika Viscoflow-28, and Sika Viscocrete 20He admixtures underscored their pivotal role in modifying concrete properties in both fresh and hardened states.

The study was conducted in three phases: material identification through tests such as particle size analysis, sand equivalence, specific gravity, and bulk density; determination of concrete components with and without admixture, followed by preparation; and a comparative study of different formulations.

Results indicate that compressive strengths of concretes formulated without admixture at 7 and 28 days lag behind those formulated with admixture, based on the DREUX GORISSE method. Key findings include the Sika Viscocrete 20He admixture acting as a fluidizer, significantly enhancing compressive strength (30 to 50 MPa) with an equivalent concrete slump of 7.5 cm. The incorporation of admixtures in our formulation demonstrated a progressive increase in various resistances, affirming their transformative role in elevating concrete quality.

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Appendix

Table A1: Particle size analysis of Sand 0/5; density: $1{,}415\ g/cm^3$.

Module	Strainer	Sieve in mm	Weight of cumulative refusals	Refusal in %	Passing in %	Initial dry weight
50	100	80	0	0.00	100.00	2879g
49	80	63	0	0.00	100.00	
48	63	50	0	0.00	100.00	
47	50	40	0	0.00	100.00	
46	40	31.5	0	0.00	100.00	
44	25	20	0	0.00	100.00	
43	20	16	0	0.00	100.00	
42	16	12.5	0	0.00	100.00	
41	12.5	10	0	0.00	100.00	
40	10	8	0	0.00	100.00	
39	8	6.3	29	1.02	98.98	
38	6.3	5	38	1.34	98.66	
35	3.15	2.5	95	3.36	96.64	
32	1.6	1.25	395	14.01	85.99	
29	0.63	0.63	1388	49.23	50.77	
26	0.4	0.315	2602	92.30	7.70	
23	0.2	0.16	2760	97.90	2.10	
20	0.1	0.08	2777	98.51	1.49	

Table A2: Particle size analysis of gravel 5/15; density: $1{,}408 g/cm^3$.

Module	Strainer	Sieve in mm	Weight of cumulative refusals	Refusal in %	Passing in %	Initial dry weight
50	100	80	0	0.00	100.00	4787g
49	80	63	0	0.00	100.00	
48	63	50	0	0.00	100.00	
47	50	40	0	0.00	100.00	
46	40	31.5	0	0.00	100.00	
44	25	20	0	0.00	100.00	
43	20	16	352	7.35	92.65	
42	16	12.5	2331	48.69	51.31	
41	12.5	10	4115	85.96	14.04	
40	10	8	4620	96.51	3.49	
39	8	6.3	4745	99.12	0.88	
38	6.3	5	4760	99.43	0.57	
35	3.15	2.5	4764	99.51	0.49	
32	1.6	1.25	4768	99.60	0.40	
29	0.63	0.63	4773	99.70	0.30	
26	0.4	0.315	4780	99.85	0.15	
23	0.2	0.16	4782	99.85	0.15	
20	0.1	0.08	4785	99.95	0.05	

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Table A3: Particle size analysis of gravel 15/25.

Module	Strainer	Sieve in mm	Weight of cumulative refusals	Refusal in %	Passing in %	Initial dry weight
50	100	80	0	0.00	100.00	8436g
49	80	63	0	0.00	100.00	
48	63	50	0	0.00	100.00	
47	50	40	0	0.00	100.00	
46	40	31.5	0	0.00	100.00	
44	25	20	0	0.00	100.00	
43	20	16	4277	50.69	49.31	
42	16	12.5	7688	91.13	8.87	
41	12.5	10	8243	97.71	2.29	
40	10	8	8383	99.37	0.63	
39	8	6.3	8411	99.70	0.30	
38	6.3	5	8415	99.75	0.25	
35	3.15	2.5	8415	99.75	0.25	
32	1.6	1.25	8415	99.75	0.25	
29	0.63	0.63	8415	99.75	0.25	
26	0.4	0.315	8415	99.75	0.25	
23	0.2	0.16	8415	99.75	0.25	
20	0.1	0.08	8415	99.75	0.25	

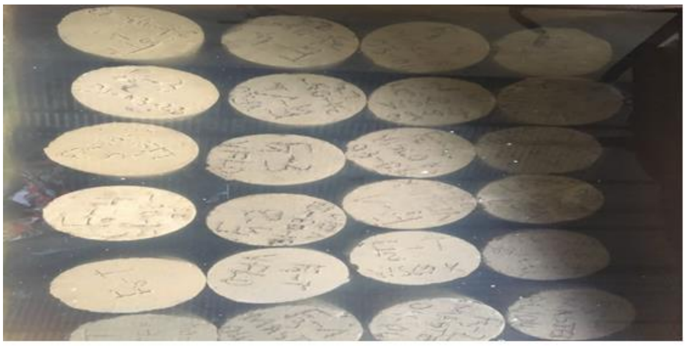

Figure A1: Storage of test pieces in a container.

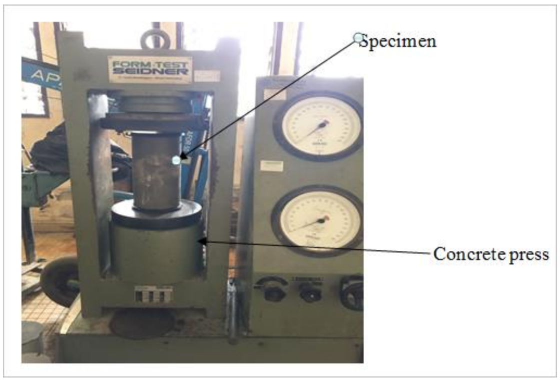

Figure A2 : Compression tests.

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