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Suitability Assessment of Superplasticizers for Developing High-Performance Self-Compacting Concrete

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Abstract

There has been a lot of interest shown regarding self-compacting concrete (SCC) in construction engineering because of its good flow properties and the fact that it can fill complex shapes without any need for further compaction. Proper amounts of superplasticizer are required to enhance the compressive strength of self-compacting concrete (SCC). The present work examines the influence of two types of superplasticizer namely Aura Type 1 and Tech Type 2 in fresh and hardened concrete properties of self-compacting concrete (SCC) exposed to hot weather conditions. Tests for compression strength (24 cubes, 150 mm³) were done after 7, 28 and 56 days and flexural strength (18prisms, 100 × 100 × 500 mm) at7, 28 and 56 days according to BS 1881. Tech exhibited 660 mm slump flow and 0.73 L-Box ratio; Aura showed 730 mm slump flow and 0.68 L-Box ratio. As for the Tech-SCC mixture, its compressive strength after seven days was 38 MPa; after 28 days, it was 52 MPa; and after 56 days, it stood at 53 MPa. When it comes to the Aura-SCC mixture, its compressive strength after seven days was 36 MPa; after 28 days, it was 49 MPa; and after 56 days, it was 51 MPa. This is very important data to help understand how to determine the right amount of superplasticizer in order to achieve better compressive strength.

Keywords: Self-Compacting Concrete (SCC), Superplasticizer.

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تقييم مدى ملاءمة الملدنات الفائقة لتطوير خرسانة ذاتية الدمك عالية الأداء

سعد جابر أبو جرير، صبحية سعد عبد الله
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الملخص

لقد حظيت الخرسانة التي لا تحتاج إلى دمك يدويا باهتمام كبير في مجال البناء. ذلك لأنها تتميز بخواص تدفق جيدة وقدرة على ملء الأشكال المعقدة بسهولة. لتحقيق ذلك، هناك حاجة إلى إضافة كميات مناسبة من المواد الكيميائية الخاصة. هذا البحث يدرس تأثير نوعين مختلفين من هذه المواد على الخصائص الفيزيائية للخرسانة. تم إجراء اختبارات للخرسانة بعد مرور 7 و28 يوم و56 يوما لتقييم مقاومتها للضغط. كما تم إجراء اختبارات للخرسانة بعد مرور 7 و28 يوم و56 يوما لتقييم مقاومتها للانحناء. أظهرت النتائج أن خلطة Tech تتميز بخصائص تدفق جيدة، مع مقاومة للضغط تبلغ 38 ميجا باسكال بعد أسبوع و52 ميجا باسكال بعد 28 يوم و53 ميجا باسكال بعد 56 يوم. بينما بلغت مقاومة خلطة Aura للضغط 36 ميجا باسكال بعد أسبوع و49 ميجا باسكال بعد 28 يوما 51, .ميجا باسكال بعد 56 يوم.

هذه النتائج مهمة جدا لمهندسي البناء لفهم كيفية تحسين الخصائص الفيزيائية للخرسانة.

الكلمات المفتاحية: الخرسانة ذاتية الدمك، الملدنات.

1. Introduction

There is a growing concern regarding the application of self-compacting concrete (SCC) within the construction industry, due to its special characteristics, particularly its great fluidity, as well as the ability to compact formworks without any assistance from external forces. While regular concrete does not require additives to achieve great fluidity, SCC needs chemicals like superplasticizers to achieve great fluidity as well as some other qualities. Regrettably, self-compacting concrete is sensitive to changes in temperature, type, and number of superplasticizers used; hence it may fail to operate effectively in some circumstances, especially Libya [1]. But

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the performance of self-compacting concrete is greatly affected by the nature and quantity of superplasticizers, and even by temperature conditions that often prevail in warm climatic zones, like Libya. In such cases, the hydration process of the cement becomes very fast, resulting in quick loss of workability, high requirement for water, and problems in attaining uniformity in its fresh state. Hence, the use of superplasticizer in this case becomes necessary to ensure proper flowability, passing capacity, and non-segregation of SCC. In spite of the increased application of SCC in current construction practices, choosing an appropriate type of superplasticizers still poses problems, particularly in situations where the construction material used is locally sourced and subjected to hot weather conditions. In developing countries like Libya, there are no guidelines on how to select and dose superplasticizers to ensure the required balance between fresh concrete characteristics (workability and passing ability) and hardened concrete characteristics (compressive and flexural strength). Moreover, the combination of superplasticizers and elevated temperatures at the time of concrete mixing and placement will result in faster deterioration of workability. There is not enough information comparing commercial superplasticizers in such circumstances [2,3].
The purpose of this paper is to examine the characteristics of SCC blends having two super plasticizers at hot environmental temperatures and to suggest appropriate selection criteria for such materials that can improve their mechanical performance.

2. Literature Review

There have been several researches done about the impact of superplasticizers on the performance of self-compacting concrete in both fresh and hardened state. Some of the widely used superplasticizers include Polycarboxylate Ether (PCE), Sulfonated Naphthalene Formaldehyde (SNF), and Sulfonated Melamine Formaldehyde (SMF). Out of all the above-mentioned superplasticizers, PCE is known to be highly effective due to its efficiency in minimizing the amount of water content. Neville [4]

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has stated that by carefully selecting the optimum amount of superplasticizer used in SCC, there will be a significant reduction in water-cement ratio without affecting the workability, thereby resulting in higher compressive strength of 20-30%. Nonetheless, it must be emphasized that this increase in strength was due to the decrease in water content rather than the admixture.

Gong et al. [5] performed a comparative study to investigate the effects of PCE, SNF, and SMF on workability, mechanical properties, and microstructure. The outcomes revealed that PCE-type superplasticizers were capable of producing better slump flow and passing characteristics than SNF and SMF types, which required higher dosages to produce comparable fresh concrete properties. This evidence highlights the effectiveness of PCE superplasticizers in high-performance SCC. Concerning local materials, it is noted that an investigation into SCC involving the use of aggregates from Gharyan, Libya, stressed the significance of aggregate water requirements and surface area. In this regard, aggregate properties such as absorption and hardness may differ depending on the source in Libya, for instance, Gharyan, Zliten, and Benghazi.

Edamatsu et al. [6] demonstrated that SCC can achieve adequate flowability using superplasticizers alone, without the need for mineral fillers. Their study recommended an optimum superplasticizer dosage of 0.75% by cement weight for standard conditions. In comparison, the present study uses higher dosages due to differences in local aggregate characteristics, cement type, and hot climate conditions, which accelerate workability loss. Table 1, summarize the some previous studies.

Table 1 Summary of Previous Studies on Suitability Assessment of Superplasticizers for High-Performance SCC.

Researcher(s) / Source	Year	Main Topic	Study Type
Abril-Fernández et al.	2025	Systematic review of superplasticizers' influence on high-performance concrete	Literature Review
Samir Hamdo uni, et al.	2026	Optimization of self-compacting concrete fresh	Experimental / Analytical

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Researcher(s) / Source	Year	Main Topic	Study Type
		properties and compressive strength using response surface modelling of superplasticizer	
Das, S. (NBM&CW)	2024	Compatibility study of superplasticizers (PCE) with cement in SCC through a practical case study	Case Study / Experimental
AlHassan, M.K. et al. (Springer)	2023	Comprehensive review of the scientific fundamentals of new-generation superplasticizers	Literature Review
Hameed, A.H. (University of Diyala)	2012	Experimental study on the effect of Glenium superplasticizer dosage on SCC workability and determination of the optimal range	Experimental
Cyr, M. & Mouret, M. (ACI)	2003	Use of cement pastes to characterize rheological behavior and link it to SCC mix design	Experimental (Paste-based)

3. Experimental Program

This section details the materials used in the experimental program, their properties, the mix design, the casting of specimens, and the testing procedures for both fresh and hardened concrete.

3.1 Materials

We confirm that the Ordinary Portland Cement (OPC) used in all concrete mixes was locally sourced from the Zliten Cement Plant (Libyan Cement Company), located in the city of Zliten, Libya. The physical properties and chemical compositions of OPC is provided in Table 2.

Table 2: Physical Properties of Cement

Chemical composition (mass %)		Physical properties	
Items	Value	Items	Value
Silicon dioxide (SiO_2)	20.14	Specific gravity	3.15
Aluminum oxide (Al_2O_3)	5.91	Specific surface area (m^2/g)	2977

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Ferric Oxide (Fe2O3)	2.99	Strength activity index at 3 days (MPa)	26
Calcium oxide (CaO)	62.9	Strength activity index at 28 days MPa	44
Magnesium Oxide (MgO)	1.59		
Sodium oxide (Na_2O)	0.18		
Potassium oxide (K_2O)	0.88		
Sulfur oxide (SO_3)	2.11		
Phosphorus oxide (P_2O_5)	0.9		
LOI	0.4		

Coarse aggregate of different maximum size viz, 19 mm, 14 mm was obtained from the quarries of Al-Alus in Al-Kums area. The coarse aggregate has a specific gravity of 2.72, water absorption of 0.41 as presented in Table 2. Figure 1 provides a graphical representation of the particle size distribution of the combined coarse aggregate (Aggregate C) shown in Table 3. The graph allows for easy visual comparison with standard specification limits.

Table 3: Sieve Analysis Results for Coarse Aggregate Samples

Sieve Size (mm)	Passing (%) Aggregate B	Passing (%) Aggregate A	Combined Aggregate C	BS 882:1992 Limits
20	100	99.43	99.66	90 - 100
14	99.81	51.97	71.11	40 - 80
10	98.70	9.06	44.92	30 - 60
5	5.55	0.4	2.45	10-0

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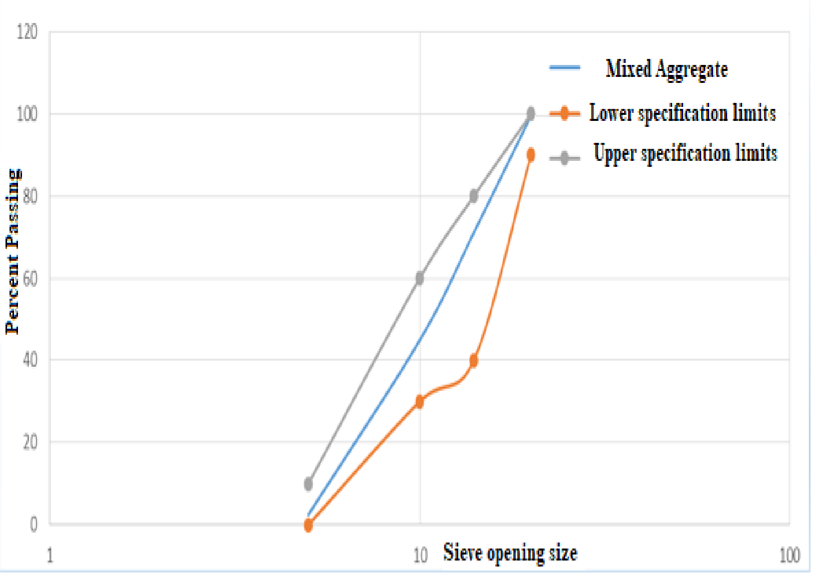

Fig. 1: Particle Size Distribution (Grading Curve) of Combined Coarse Aggregate

Table 4 summarizes the physical and mechanical properties of the combined coarse aggregate (Aggregate C) used in this study. All test results are compared against the limits specified in BS 882:1992, which is the British Standard for aggregates sourced from natural sources for use in concrete.

Table4: Physical and Mechanical Test Results for Coarse Aggregate According to British Standards

Test According to Specifications	Combined Coarse Aggregate (C)	BS 882:1992 Limits
Specific Gravity	2.72	2.50 – 2.75
Absorption Rate	0.41%	Less than 3%
Moisture Content	1.73%	-
Bulk Density (kg/m³)	1530	-
Aggregate Crushing Value (ACV)	23.8%	Less than 25%

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Aggregate Impact Value (AIV)	20.2%	Less than 45%
Los Angeles Abrasion Value	21.6%	Less than 50%

Natural sand with maximum size of 1.2 mm, used as a fine aggregate was collected from Zlitan area. The fine sand has a fineness modulus of 2.7, specific gravity of 2.66 and water absorption of 0. 85 %. As shown in Table 5 and 6.

Table 5.: Sieve Analysis Results for Fine Aggregate Samples

Sieve Size (mm)	Passing (%) Sand (D)	BS 882:1992 Limits (Zone 4)
5	100	100 – 95
2.36	99.98	100 – 95
1.18	99.94	100 – 90
0.6	99.46	100 – 80
0.3	49	50 – 15
0.15	4.08	15 – 0

Table 6: Physical and Mechanical Test Results for Fine Aggregate

Test	Sand (D)	BS 882:1992 Limits
Blending Percentage (%)	%22	-
Fineness Modulus	1.48	-
Specific Gravity	2.66	2.75 – 2.50
Absorption Rate	%0.85	Less than 3%

Based on the results obtained from Figure 2, it is evident that the fine aggregate falls within the limits of the British Standard (BS 882:1992).

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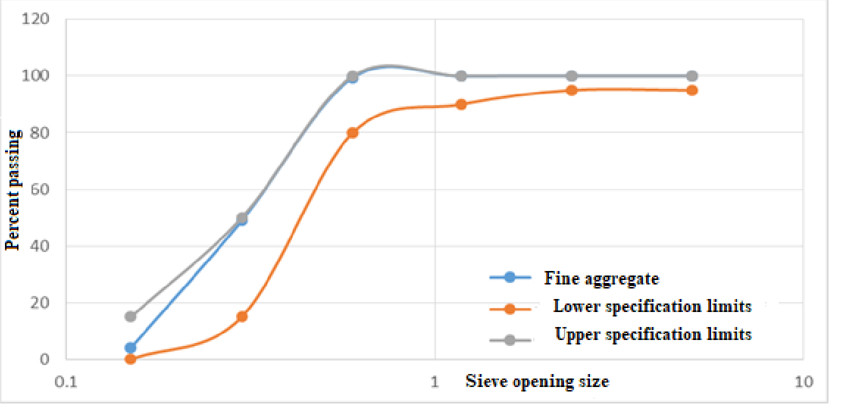

Fig. 2.: Particle Size Distribution (Grading Curve) of Sand and BS 882 Limits

Water: Potable water conforming to Libyan Standard No. 294 (1988) was used. Testing was conducted at the Industrial Research Center, Tajoura.

Two types of superplasticizers were procured from the local market, and their key characteristics are summarized in Table 7.

Table 7: Properties of Superplasticizers

Manufacturer	SP Name	SP Code	Dosage (% of cement)	Chemical Base	Color
FOSROC	Aura	Aura-SCC	0.8-1.5%	Polycarboxylate Ether (PCE)	Brown
Agel	Tech	Tech-SCC	0.6-2%	Polycarboxylate (PCE)	Dark Brown

3.2 Mix Design and Specimen Preparation

a. Mix Proportions

A constant mix proportion was used for all SCC mixes, based on standard design methods, with a water-to-cement (w/c) ratio of 0.4. The dosage of superplasticizer was set at 1.5% of cement weight for all mixes, The mix proportions per cubic meter are detailed in Table 8.

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Table 8: Concrete Mix Proportions (per 1 m³)

Mix Code	Cement (kg)	w/c Ratio	Water (kg)	Fine Agg. (kg)	Coarse Agg. (kg)	SP Type	SP Dosage (% of cement)	SP Weight (kg/m³)
Tech-SCC	490	0.40	196	540	1000	Tech	1.5%	8.82
Aura-SCC	490	0.40	196	540	1000	Aura	1.5%	6.86

b. Mixing Procedure

The mixing procedure was based on the method described by Grunewald & Walgreen. Cement and sand were dry-mixed for 10 seconds. Then, 80% of the mixing water and the superplasticizer were added and mixed for 110 seconds. Finally, the coarse aggregate and the remaining water were added, and mixing continued for another 60 seconds.

c. Specimen Casting and Curing

For each mix, twenty-four cubes are cast for compressive strength tests, and sixteen 100×100×500mm prisms are cast for flexural tests, each at **7**, 28 and 56 days. The molds are cleaned, oiled, and assembled. The specimens are left to set for 24 hours after casting, and then they are demolded and left in the water tanks maintained at a temperature of 20 degrees Celsius until the day of the test.

d. Testing Concrete

Fresh SCC properties were evaluated using two standard tests according to EFNARC guidelines.

- Slump Flow Test: This test measures the free, horizontal flow of SCC in the absence of obstructions. The diameter of the concrete spread was measured in two perpendicular directions. A value between 550-850 mm is considered acceptable for SCC.

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- L-Box Test: This test assesses the passing ability of SCC through reinforcement. The L-Box apparatus consists of a vertical section and a horizontal section separated by a gate with reinforcing bars. The ratio of the final heights of concrete at the end of the horizontal section (H2) to the beginning (H1) is calculated. A ratio (H2/H1) between 0.75 and 1.0 indicates good passing ability.

- Compressive Strength Test: The 150*150*150 mm cubes were tested in compression at 7, 28 days and 56 days using a compression testing machine. The load was applied at a constant rate of 0.25 MPa/s until failure, following BS 1881: Part 116:1983.

-Flexural Strength Test: The 100×100×500 mm prisms were tested at 28 days under two-point loading (four-point bending) to determine the modulus of rupture. The test was conducted in accordance with BS 1881: Part 118:1983.

- Ultrasonic Pulse Velocity (UPV) Test: The non-destructive ultrasonic pulse velocity test was performed on the concrete cubes of size 150 mm at the ages of 7 days, 28 days, and 56 days as per BS EN 12504-4. This test was employed to study the homogeneity of the structure and relative quality of the SCC. The longitudinal pulse velocity is calculated by the measurement of the time taken by the pulse to travel through the concrete cube.

4. Results and Discussion

4.1 Fresh Concrete Properties

The results of the Slump Flow and L-Box tests for all SCC mixes are presented in Table 9 .

Table 9: Fresh Concrete Test Results

Mix Code	Slump Flow (mm)	L-Box Ratio (H2/H1)
Tech -SCC	660	**0.73**
Aura-SCC	730	0.68

Aura-SCC achieved the highest slump flow value of **730 mm**, indicating excellent fluidity and spreading ability under its own weight. This mix demonstrates superior workability and flowability.

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-Tech-**SCC** recorded **660 mm**, which is still within the acceptable range according to EFNARC guidelines (typically 600–750 mm for SCC), but it exhibits lower flowability compared to Aura-SCC.

-Tech-**SCC** recorded a higher ratio of **0.73**, indicating better passing ability through reinforcement bars without segregation or blocking.

-Aura-SCC recorded **0.68**, which is also within the acceptable limit (typically ≥ 0.6 according to EFNARC), but it shows slightly lower passing ability compared to Tech-SCC.

4.2 Hardened Concrete Properties

1. Compressive Strength

The compressive strength results for all mixes at 7 and 28 days and 56 are presented in Table 10 and Figure 3.

Table 10: Compressive Strength Results

Mix Code	Compressive Strength (MPa)		
	7 days	28 days	56 day
Tech -SCC	38	52	53
Aura-SCC	36	49	51

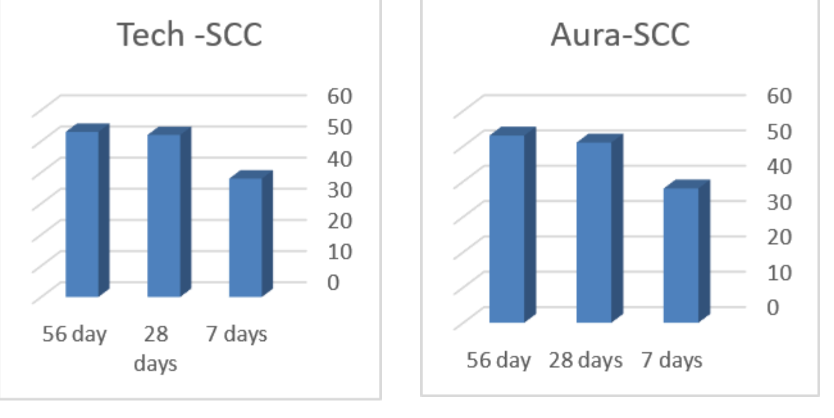

Figure 3. Compressive Strength Results

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While both superplasticizers successfully produced SCC that meets high-performance standards, **Tech-SCC** demonstrated superior mechanical properties. These results are highly reliable and provide a strong scientific basis for selecting polycarboxylate ether-based admixtures for local high-strength applications

2. Flexural Strength

The flexural strength (modulus of rupture) results at 7, 28 and 56 days are shown in Table 11.

Table 11: Flexural Strength Results (7,28 and 56 Days)

Mix Code	Flexural Strength (MPa)		
	7	28	56
Tech -SCC	4.5	6.7	7
Aura-SCC	4.2	5.9	6.3

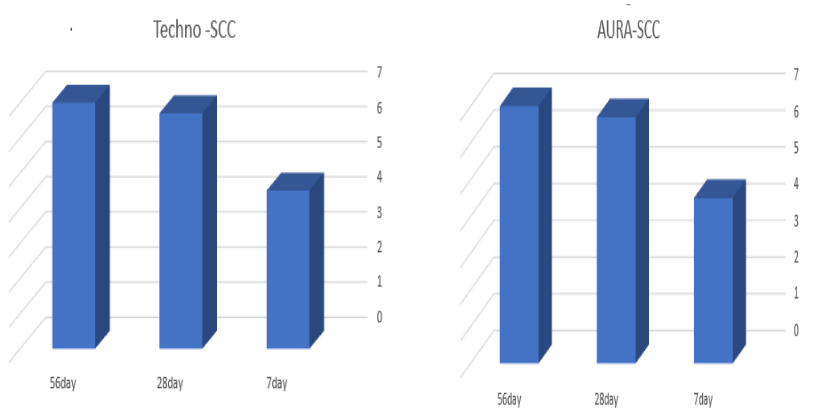

Figure 4. Flexural Strength Results

Both SCC in Figure 4, mixes showed a continuous increase in flexural strength with age, which is expected due to ongoing cement hydration and microstructural densification. The rate of increase was highest between 7 and 28 days and slowed between 28 and 56 days, indicating that most of the strength development occurred within the first 28 days.

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3. Ultrasonic Pulse Velocity (UPV) Results The results of the Ultrasonic Pulse Velocity (UPV) tests for both SCC mixtures at 7, 28, and 56 days are presented in Table 12. The UPV values serve as a critical indicator of the concrete's internal compactness, quality, and density.

Table 12: Ultrasonic Pulse Velocity (UPV) Test Results

Mix Code	7 Days (km/s)	28 Days (km/s)	56 Days (km/s)	Concrete Quality Grading (BS EN 12504-4)*
Tech-SCC	4.12	4.55	4.62	Excellent (> 4.5 km/s)
Aura-SCC	3.95	4.38	4.41	Good (3.5 - 4.5 km/s)

Table 13 Present the comparison and an analysis of how my results align with established literature.

Table13: Comparison of Experimental Results with Recent Literature

Parameter	My Study	Abril-Fernández et al. (2025) – Systematic Review
Superplasticizer Types	Polycarboxylate Ether (PCE) – Tech. AURAMIX – TYPE 1	PCE, SNF, SMF, and hybrid formulations
Slump Flow (mm)	660–730 mm (highest: Aura-SCC at 730 mm)	600–750 mm typical for SCC; PCE-based SPs showed superior flowability (up to 750 mm)
L-Box Ratio (H2/H1)	0.68–0.73 (highest: Tech-SCC at 0.73)	0.75–1.0 considered acceptable; PCE-based SPs generally achieved ratios >0.8
Compressive Strength (MPa)	MPa (28–56 5349–days) (highest: Techno-SCC at 57 MPa after 56 days)	PCE-based SPs increased compressive strength by 20–40% compared to controls; values ranged from 50–80 MPa depending on w/c and mix design
Flexural Strength (MPa)	5.9–7.0 MPa (28–56 days) (highest: Techno-	PCE-based SPs improved flexural strength by 15–30%;

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Parameter	My Study	Abril-Fernández et al. (2025) – Systematic Review
	SCC at 7.0 MPa after 56 days)	typical values ranged from 5.5–8.5 MPa for SCC
SP Dosage (% cement)	1.5%	Optimum dosage reported: 0.75–2.0%, depending on SP type and mix composition

Summary of Comparison

Fresh Properties: Your results align with the literature, showing that PCE-based superplasticizers provide excellent slump flow and passing ability. However, the L-box ratios in your study (0.68–0.73) were slightly below the typical range (0.75–1.0) reported in the review, possibly due to local aggregate characteristics or mix proportioning.

Mechanical Properties: Your compressive strength results (49–57 MPa) fall within the range reported in the literature for PCE-based SCC. The flexural strength values (5.9–7.0 MPa) are also consistent with the 15–30% improvement cited in the review. SP Dosage: Your dosage (1.5%) is slightly higher than the optimum (0.75–2.0%) reported in the review, but this may be justified by the need to maintain workability with local materials.

5. Conclusions

Based on the experimental results of SCC mixes produced with two polycarboxylate-based superplasticizers (Tech at 1.5% and Aura at 1.5%) using local Libyan materials, the following key conclusions are drawn:

1. Fresh Properties

- Aura-SCC achieved higher slump flow (730 mm vs. 660 mm), representing a +10.6% advantage.
- Tech-SCC achieved better passing ability (L-Box = 0.73 vs. 0.68), a +6.8% advantage.
- Both mixes failed the EFNARC L-Box requirement (≥ 0.80).

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2. Compressive Strength

- Tech-SCC achieved the highest compressive strength at all ages: 52 MPa at 28 days and 53 MPa at 56 days.
- This represents a +6.1% advantage over Aura-SCC (49 MPa at 28 days).
- Most strength development occurred within the first 28 days (36–37% gain), with minimal increase thereafter (2–4%).

3. Flexural Strength

- Tech-SCC achieved the highest flexural strength: 6.7 MPa at 28 days and 7.0 MPa at 56 days.
- This represents a +13.6% advantage over Aura-SCC (5.9 MPa at 28 days).
- Flexural-to-compressive strength ratios were 12.9% (Tech-SCC) and 12.0% (Aura-SCC), both within the typical 10–15% range.
- The UPV test confirmed the superior internal structure and compactness of the **Tech-SCC** mix, which achieved an "Excellent" quality rating with a velocity of **4.62 km/s** at 56 days. This represents a higher pulse velocity compared to Aura-SCC, reinforcing the mechanical test results and verifying that Tech-scc enhances microstructural density when using local materials.

4. Final Recommendation

- Tech-scc (1.5% dosage) is recommended for high-performance SCC using local Libyan materials, as it provides higher strength (+6.1% compressive, +13.6% flexural) and better passing ability (+6.8%).
- However, additional optimization (e.g., viscosity-modifying admixture, aggregate grading) is required to meet the EFNARC L-Box requirement of ≥ 0.80.

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6. Limitations and Recommendations

- Neither mix met the EFNARC L-Box requirement of ≥ 0.80, indicating insufficient passing ability for densely reinforced sections.
- Aura-SCC showed signs of segregation (slump flow 730 mm, L-Box 0.68). This mix is not recommended for structural applications without modification.
- Tech-SCC is the better performer but still requires optimization to achieve L-Box ≥ 0.80.
- Future studies should consider:
    - Adding viscosity-modifying admixtures (VMA) to improve stability.
    - Adjusting aggregate grading to reduce blocking.
    - Testing intermediate dosages between 1.5%.

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