

Investigation into the Effects of Polystyrene Beads on the Properties of Self-Compacting Concrete

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ARTICLE HISTORY

Received 02 August 2026
Revised 21 September 2026
Accepted 01 October 2026
Online 07 October 2026

KEYWORDS

Self-Compacting Concrete;
Compressive Strength;
Expanded polystyrene (EPS);
Cork granules;
Lightweight Concrete;
Fresh Properties.

ABSTRACT

This study investigates the effects of incorporating expanded polystyrene (EPS) cork granules into self-compacting concrete (SCC) to produce lightweight concrete (LWC). It incorporates different percentages (0%, 1.5%, 3%, 5%, and 10%) of expanded polystyrene (EPS) cork granules as a partial cement replacement. It then evaluates the effect of the expanded polystyrene (EPS) cork granules on the bulk density, indirect compressive strength, and tensile strength of the modified concretes. It performs the Slump Flow + T50 test to evaluate the fresh concrete properties and determine its diffusion diameter and flow time. Except for the mixture incorporated with 10% cork, the flow diameter for all mixtures is within the specified range. Concretes with higher polystyrene content have higher viscosity and smaller diffusion diameter. The L-Box test assessed the passing ability capability of concrete when poured into densely reinforced sections. Except for the concrete containing 10% cork, all mixtures exhibited self-leveling capability within the specified limit. The V-Funnel test showed that the concrete flow characteristics were within the EFNARC limit, although the value for the concrete with 10% expanded polystyrene (EPS) cork granules approached the upper limit. The total density of the hardened concrete with 10% expanded polystyrene (EPS) cork granules decreased by approximately 47.6%. However, its compressive strength at 28 days decreased considerably by approximately 99%. Similarly, the indirect tensile strength of concrete containing 5% expanded polystyrene (EPS) cork granules decreased after 28 days. The testing device could not register the concrete's resistance because of its weak tensile strength. The modulus of elasticity of the concrete with 10% cork decreased by about 95%. In conclusion, expanded polystyrene (EPS) cork granules self-compacting LWCs can be used for non-load-bearing construction partitions. This approach promotes environmental sustainability by reducing the accumulation of cork (polystyrene) waste.

دراسة تأثير حبيبات البوليسترين على خواص الخرسانة ذاتية الدمك

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المخلص	الكلمات المفتاحية
تناول هذه الدراسة تأثير إضافة حبيبات الفلين المصنوعة من البوليسترين الممدد (EPS) إلى الخرسانة ذاتية الدمك (SCC) بهدف إنتاج خرسانة خفيفة الوزن (LWC). وقد تم استخدام نسب مختلفة من حبيبات البوليسترين الممدد (EPS)، وهي 0%، و1.5%، و3%، و5%، و10%، بوصفها إحلالاً جزئياً للأسمنت. كما تم تقييم تأثير حبيبات البوليسترين الممدد (EPS) في كل من الكثافة الحجمية، ومقاومة الضغط غير المباشر، ومقاومة الشد للخرسانة المعدلة. أُجري اختبار انتشار الهطول وزمن (Slump Flow + T50) لتقييم خصائص الخرسانة الطازجة وتحديد قطر الانتشار وزمن التدفق. وباستثناء الخلطة التي تحتوي على 10% من حبيبات الفلين، جاءت أقطار الانتشار لجميع الخلطات ضمن الحدود المحددة. وأظهرت الخرسانة التي تحتوي على نسب أعلى من البوليسترين لزوجة أكبر وقطر انتشار أصغر. كما تم استخدام اختبار صندوق L (L-Box) لتقييم قدرة الخرسانة على المرور والانسياب عند صبها في المقاطع ذات التسليح الكثيف. وباستثناء الخرسانة المحتوية على 10% من حبيبات الفلين، أظهرت جميع الخلطات قدرة على التسوية الذاتية ضمن الحدود المسموح بها. وأظهر اختبار قمع V (V-Funnel) أن خصائص تدفق الخرسانة كانت ضمن الحدود المحددة من قبل (EFNARC) على الرغم من أن قيمة الخرسانة المحتوية على 10% من حبيبات البوليسترين الممدد (EPS) اقتربت من الحد الأعلى المسموح به. انخفضت الكثافة الكلية للخرسانة المتصلدة المحتوية على 10% من حبيبات البوليسترين الممدد (EPS) بنسبة بلغت نحو 47.6% وفي المقابل، انخفضت مقاومتها للضغط بعمر 28 يوماً بصورة كبيرة، وبنسبة	الخرسانة ذاتية الدمك مقاومة الضغط حبيبات البوليسترين الممدد (EPS) حبيبات الفلين الخرسانة خفيفة الوزن الخواص الطازجة

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https://doi.org/10.63318/waujpasv4i2_56

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بلغت نحو 99% وبالمثل، انخفضت مقاومة الشد غير المباشر للخرسانة المحتوية على 5% من حبيبات البوليسترين الممدد (EPS) بعد 28 يومًا. ولم يتمكن جهاز الاختبار من تسجيل مقاومة الخرسانة للشد نتيجة انخفاض مقاومتها للشد إلى مستوى ضعيف جدًا. كما انخفض معامل المرونة للخرسانة المحتوية على 10% من حبيبات الفلين بنسبة بلغت نحو 95% وبناءً على النتائج، يمكن استخدام الخرسانة خفيفة الوزن ذاتية الدمك المحتوية على حبيبات الفلين المصنوعة من البوليسترين الممدد (EPS) في تنفيذ القواطع الإنشائية غير الحاملة. ويسهم هذا النهج في تعزيز الاستدامة البينية من خلال الحد من تراكم نفايات الفلين (البوليسترين) والاستفادة منها في إنتاج مواد بناء خفيفة الوزن.

Introduction

Self-compacting concrete (SCC) is a homogeneous, highly fluid concrete that consolidates under its own weight. It remains homogeneous and flows easily into narrow spaces with dense rebar configurations without mechanical vibration [1,2]. In 1986, Okamura pioneered SCC development to address challenges in constructing heavily reinforced buildings. Ozawa later refined the initial model, advanced SCC production, and facilitated applications in Japan, China, and the U.S. This material innovation enhanced quality and efficiency while reducing construction time and cost [3,4].

Population growth, rapid urbanization, and rising consumption rates have worsened the accumulation of ecologically damaging solid waste [5]. Of these pollutants, industrial cork waste (polystyrene) is very damaging to the environment. The many benefits of polystyrene make it indispensable in many real-world applications. One particular benefit of polystyrene is that it is easy to compress and process into consumer goods [6]. However, the cork industry generates large volumes of cork waste that does not readily decompose in nature and causes significant environmental degradation. Therefore, it is essential to manage cork waste through recycling and giving it a second life in other products [7].

One challenge of using high-porosity lightweight aggregates is that they absorb significant amounts of mixing water. Therefore, more water is needed to achieve adequate workability, which in turn requires increasing the cement content, although it does not increase the mixture's strength. A viable alternative is utilizing non-absorbent artificial ultra-lightweight aggregates [8], including polystyrene (EPS) cork granules [9–12].

A previous study on self-compacting, lightweight concrete (LWC) incorporated different percentages of polystyrene (EPS) cork granules (0%, 1.5%, 3%, 5%, and 10%) by weight of cement to determine the concrete's tensile and compressive strength and the optimal polystyrene content for these parameters. [13] investigated the impact of ACI on the modulus of elasticity of hardened concrete. The investigation method followed the ACI Committee ACI-8.5.1 guideline for determining the optimal polystyrene ratio.

Other studies explored the feasibility of incorporating EPS aggregate into LWC as a partial or full replacement of natural coarse and fine aggregates. Cui et al. (2016) developed an EPS concrete with a density ranging between 800 and 1200 kg/m³ and a compressive strength of 3.08 MPa at 800 kg/m³ [14].

Another study achieved a concrete strength of 10.6 MPa by replacing 80% of the natural aggregates [15]. Cadere et al. produced concrete with a strength of 8 MPa through 100% coarse aggregate replacement [16], while another study obtained a strength of 3.8 MPa by replacing 80% of fine aggregates [17].

Researchers reported enhancing concrete strength by incorporating smaller EPS [17–19]. A study incorporated

modified EPS expanded polystyrene aggregates (MEPS) as a full replacement and achieved a concrete with a strength of 12.58 MPa, a density of 980 kg/m³, and a tensile strength of 1.82 MPa [20]. EPS also altered concrete's thermal properties, where higher EPS contents reduced thermal conductivity [20]. Sayadi et al. (2016) incorporated EPS as a partial replacement for total mix materials and evaluated the mixture's fire resistance, thermal conductivity, and compressive strength [21].

The main purpose of this research is to explore the fresh and hardened mechanical properties of the self-compacting concrete made from the use of expanded polystyrene (EPS) beads as a partial replacement of cement. The fresh workability and passing ability of the mixtures are, therefore, assessed using slump flow, T50, L-box, and V-funnel tests respectively, for this investigation. In addition, it evaluates the hardened physical and mechanical properties by examining dry bulk density, 7-day and 28-day compressive strength and splitting tensile strength, as well as Young's modulus at different EPS replacement rates.

Materials used in the study

Cement

All concrete mixtures were prepared using Ordinary Portland Cement (42.5N) manufactured by Arab Union Contracting Company. It has a specific gravity of 3.15 N/m³ [23].

Water

Al-Ittihad Company supplied the potable desalinated water. It is free of pollutants, organic materials, alkalis, acids, and oils. However, any potable water is acceptable for preparing processing concrete mixtures [24].

Fine Aggregate

The natural fine aggregate for preparing the concrete mixtures was sourced from Al-Ittihad Company. The sieve analysis complied with the British specifications [25]. Table 1 presents the granular gradation of the fine aggregate, and Figure 1 shows the granular grading range. Table 2 presents the physical and mechanical properties of the fine aggregate [25].

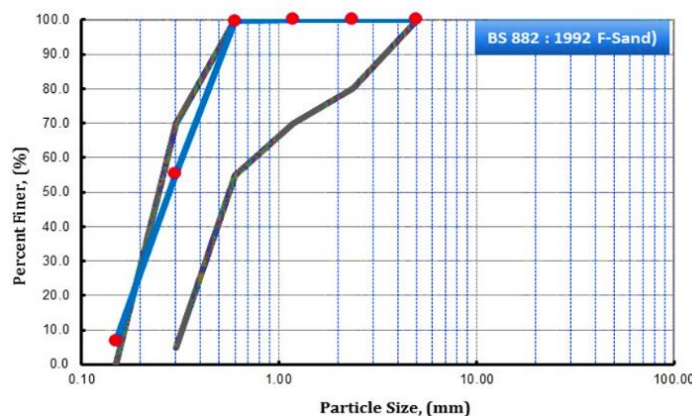


Figure 1: Granular Gradation Curve of the Fine Aggregate [BS 882–1992 F-Sand]

Table 1: Granular Gradation of the Fine Aggregate and the Allowable Limit.

Sieve size (mm)	Mass Retained (gm)	Percentage of Mass Retained	Passing (%)	Specification Limits [BS: 882-1992]
4.75	0	0	100.0	
2.36	0	0	100.0	
1.18	0	0	100.0	---
0.6	1.7	1.73	98.27	100~80
0.425	5.7	5.81	92.46	100~70
0.3	33.1	33.7	58.76	100~55
0.15	48.4	49.33	9.43	70~5
0.075	9.2	9.37	0.06	---
Fineness Modulus (F.M)		1.38		---

Table 2: Physical and Mechanical Properties of the Fine Aggregate and the Allowable Limit for the British Standard Specification.

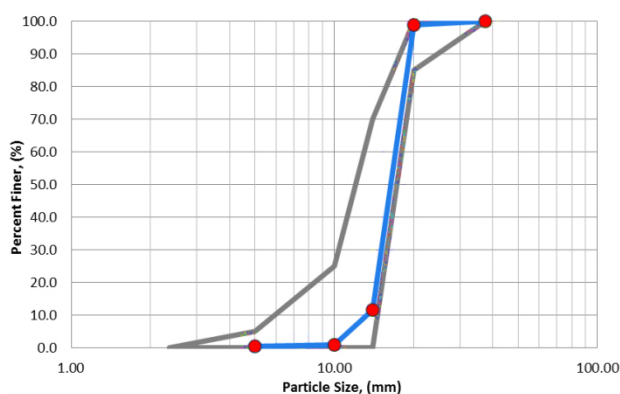
Test specification	Specification Limits	Result	Test
specific gravity	2.587	2.5 – 2.7	BS 812-2:1995
Absorption Ratio	0.47	4%	BS 812-2:1995
Coefficient of smoothness	1.38	----	---

Coarse Aggregate

The 10 mm and 0.8 mm coarse aggregates used in this study were sourced from Al-Ittihad Company. They comply with the British specifications [25]. Table 3 presents the sieve analysis results, Figure 2 shows the granular gradation scale, and Table 4 presents the physical and mechanical properties of the coarse aggregates [25–28].

Table 3: Granular Gradation of the Coarse Aggregate and the Allowable Limit.

Sieve size (mm)	Mass Retained (gm)	Mass Retained %	Passing (%)	Specification Limits [BS:882-1992]
37.5	0	0	100	100
20	0	0	100	100~85
14	474	7.51	92.49	70~0
10	854	13.53	78.96	25~0
5	639	10.12	68.84	5~0
4.75	4343	68.82	0.02	---
2	0	0	0	---
Fineness Modulus (F.M)		3.88		---

**Figure 2:** Grain Gradation Curve for the Coarse Aggregate**Table 4:** Properties of the Coarse Aggregate and the Limits Allowed by the American, Libyan, and British Standards.

Test	Result	Specification Limits	Test specification
Specific gravity	2.604	2.5 – 2.7	(ASTM C127)
Volume of unit weight	1446.4	1400 -1800 kg/ m3	(ASTM C29 C29M)
Absorption Ratio	0.64	Not more than 3%	(ASTM C128)
Impact coefficient	7.525	Not more than 30%	(L S S 257,258)
Crushing coefficient	27.65	Not more than 40%	(BS 812: Part 110:90)
Fine material %	0.63	4%	(ASTM C117)
Fineness Modulus (F.M)	3.88	----	----

Super Plasticizer

This study used Viscocrete Tempo 12, a superplasticizer manufactured by SIKA, as a chemical additive. It is a liquid polycarboxylate-based superplasticizer designed for manufacturing SCC. The cement weight ranges between 0.4 and 1.5% [29].

Polystyrene

The expanded polystyrene (EPS) granules were sourced from Al-Enmaa Pipes Company (Libya) as pre-expanded industrial-grade beads.

**Figure.3:** Polystyrene Polymer

Evaluating these beads investigates the valorization of industrial polymeric surplus and packaging materials within lightweight cementitious matrices, establishing a practical route to reduce solid polymer accumulation in landfills. The beads exhibit a closed spherical structure with a diameter of 2–3 mm, an ultra-low bulk density of 20–50 kg/m³, and a thermal conductivity (λ) between 0.031 and 0.047 W/(m · K) Figure 3 shows the polystyrene used in the study, and Table 5 presents its physical properties.

Table 5: Physical Properties of the Polystyrene.

Physical property	Results
Granule Diameter	2 - 3 mm
Density	20 – 50 kg/m ³
Thermal conductivity, λ	0.031 – 0.047 W/m.k°
Colour	White

Design, Mixing, and Pouring of the Concrete Mixtures

The flow and separation resistance of the fresh SCC concretes complied with the European recommendations (EFNARC) [30,31]. The concrete mixtures contain 0%,

1.5%, 3%, 5%, and 10% polystyrene by weight of cement. Table 6 presents the mix proportions of the material used to manufacture one cubic meter of concrete.

The percentage of EPS beads used in this investigation was incorporated as a direct partial replacement of Ordinary Portland Cement by weight (0%, 1.5%, 3.0%, 5.0% and 10%). This experimental campaign focused on the threshold behaviour and feasibility of direct binder dilution with lightweight polymeric waste, as opposed to the usual practice of substitution in the concrete design with either fine or coarse aggregate. Because of this significant difference in the specific gravity of cement (3.15), and the bulk density of EPS (20-50kg/m³), the number of EPS would expand by a substantial amount in terms of volume when replacing by mass basis. This means that with higher EPS doses (i.e. 5% and 10%), the increase in paste volume in the mixture is accompanied by a significant decrease of the volumetric binder-to-void ratio.

Table 6: Mix Proportion for One Cubic Meter.

Material	Mix				
	M1	M2	M3	M4	M5
Cement (kg/m ³)	442	435.37	428.74	419.9	397.8
Coarse Aggre 10mm (kg/m ³)	330	330	330	330	330
0.8 mm	500	500	500	500	500
Sand (kg/m ³)	840	840	840	840	840
Water (kg/m ³)	210	210	210	210	210
Polystyrene (kg/m ³)	0%	1.5%	3%	5%	10%
	0	6.36	13.26	22.1	44.2
Plasticizer (kg/m ³)	7.5	7.5	7.5	7.5	7.5

The reduction in compressive strength from 41.47MPa in the control mix to 0.82MPa when 10% EPS replaced was both influenced and controlled by two parallel physical mechanisms. First, the replacement of hydraulic cement with chemically inert EPS will lead to less formation of calcium silicate hydrate (C-S-H) gel, leaving the matrix without the continuous network of binding that is necessary to transfer the loads. Second, the weight-for-weight substitution will greatly overestimate the volumetric aggregate/void fraction due to the compressibility and hydrophobic nature of EPS material and its ultra-low bulk density (20-50kg/m³). A microstructural stress concentration due to the weak interfacial transition zone (ITZ) between the non-polar polystyrene surfaces and the cement paste leads to early matrix failure under compression. Therefore, a mixture made with a high percentage of EPS (i.e. > 5%) cannot be used for structural purposes and should only be used as non-load-bearing partitions, thermal insulating screeds or as lightweight filler blocks.

Preparing and Mixing the Materials

The solid constituents, including coarse aggregate, fine aggregate, and cement, were batched using a scale accurate to ± 50 "g", while the mixing water and liquid superplasticizer were measured using a precision balance accurate to ± 0.1 "g". Owing to the ultra-low bulk density and hydrophobic nature of the EPS beads, an optimized sequential mixing protocol was implemented to prevent particle flotation, bead agglomeration, and matrix segregation. Initially, the coarse aggregate, sand, Ordinary Portland Cement, and dry EPS beads were charged into a mechanical pan mixer and dry-mixed for 2.0 minutes to achieve a uniform dispersion of beads throughout the dry granular skeleton. Subsequently, approximately 80% of the mixing water was introduced and agitated for 1.5 minutes to

hydrate the binder grains. The remaining 20% of the water, premixed with the polycarboxylate superplasticizer, was then gradually added to prevent premature chemical absorption by the dry aggregates, followed by 2.5 minutes of continuous intensive mixing until a stable, homogeneous, self-compacting consistency was obtained. For each mix proportion, six cylindrical specimens (100 × 200mm) and six cube specimens (150 × 150 × 150 mm) were cast to evaluate the hardened physical and mechanical properties. All specimen preparation, mixing, and subsequent testing procedures were conducted at the testing facilities of the high-speed train company.

Fresh Concrete Testing

Slump Flow T50

This slump flow T50 test determined the flowability and filling capacity of the concrete mixtures by measuring the diffusion diameter and flow time as shown Figure 4(a) and (b). The flow diameters of most concrete mixtures were within the specified limit of 650 mm to 800 mm, indicating that incorporating higher percentages of polystyrene increased the mixture's flowability while reducing its diameter. Prevalence: In general, the readings were close, except for 10% that was outside the specification, as in Table 7 [31].

L-Box Test for Concrete Passing Ability

The L-box test evaluates concrete's passing ability in densely reinforced sections with variable geometry as shown Figure 4 (c). This test is directly related to viscosity. The results for all concrete mixtures, except for the mixture with 10% polystyrene, were within the specified limit (Table 7). Several parameters contributed to this deviation, including water-to-cement ratio, inconsistent aggregate size, improper mixing, or temperature fluctuations during testing [31].

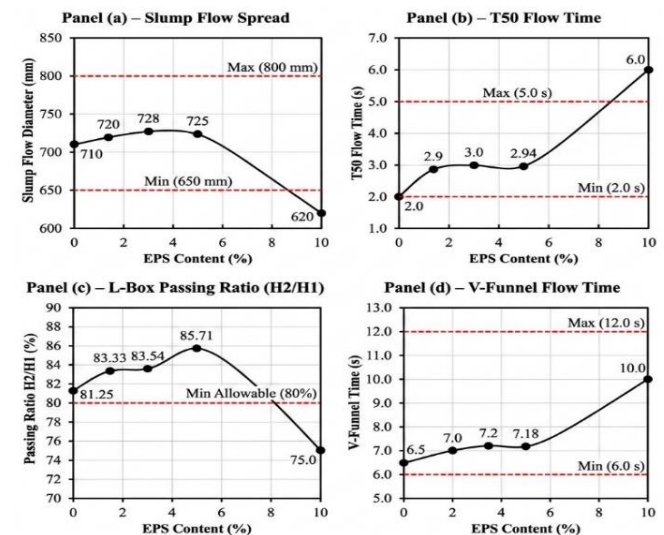


Figure 4: Fresh properties of polystyrene-modified SCC mixtures: (a) slump flow spread diameter; (b) T_{50} flow time; (c) L-box passing ratio (H_2/H_1); and (d) V-funnel flow time relative to standard EFNARC acceptance limits

Funnel (V-Funnel) for Concrete Flowability

The V-funnel test revealed that the flowability of all concrete mixtures was within the limits specified by EFNARC as shown Figure 4(d). However, the value for the mixture with 10% polystyrene was close to the specified upper limit Table 7 [31].

Hardened Concrete Testing

Table 7: Fresh Concrete Testing

Mixture	W/C ratio	Percentage of Polystyrene	V-Funnel (sec)	L-Box (H2/H1) %	T ₅₀ (Sec)	Slump Flow (mm)
1	0.4	0%	6.5	81.25	2	710
2	0.4	1.5%	7	83.33	2.9	720
3	0.4	3.0%	7.2	83.54	3	728
4	0.4	5.0%	7.18	85.71	2.94	725
5	0.4	10%	10	75	6	620
EFNAR C		Minimum value	6	80	2	650
Recommendation		Maximum value	12	100	5	800

Compressive Strength Test

The compressive strength test was conducted as specified on 150×150×150 mm Figure 5 shows compressive strength test, concrete cubes containing 0%, 1.5%, 3%, 5%, and 10% polystyrene [32]. The test evaluated how polystyrene content influences compressive strength. The concrete's pressure resistance was calculated using Equation (1).

**Fig.5: Compressive Strength Test**

$$f'_c = \frac{P}{A}, \quad (1)$$

Where: f'_c (or σ_c) = Compressive strength of the concrete (MPa or N/mm²)

P = Maximum failure load applied to the specimen (N)

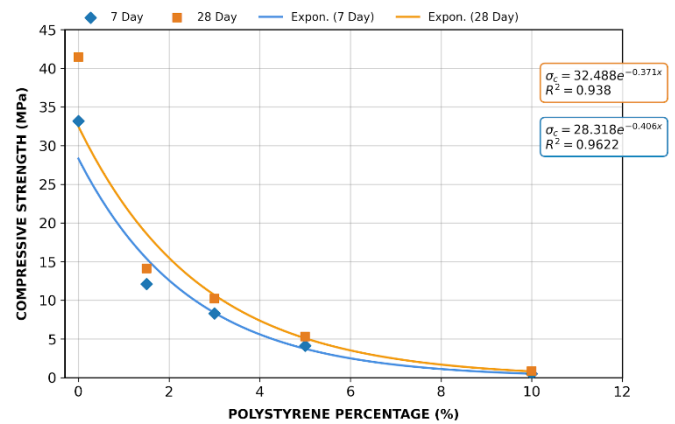
A = Cross-sectional contact area of the cube specimen (mm²), which is 150 mm × 150 mm = 22,500 mm²

Table 8 presents the compressive strength of the polystyrene-modified concrete. Figure 6 shows that pressure resistance is inversely proportional to polystyrene content.

Table 8: Compressive Strength of Polystyrene-modified Mixtures after Seven and 28 Days.

Mixture	Percentage of Polystyrene %	Compressive Strength (MPa)		Density (ton/m3)
		After 7days	After 28 days	
1	0	33.17	41.47	2.50
2	1.5	12.10	14.13	2.15
3	3.0	8.31	10.20	1.97
4	5.0	4.11	5.30	1.66
5	10	0.48	0.82	1.31

The cubes were produced, cured, and tested in accordance with BS 1881-116 and EN 12390-3

**Figure 6: Relationship Between Compressive Strength and Polystyrene Content**

Indirect Tensile Strength Test

The indirect tensile strength (Brazilian) test was conducted on 200 mm x 100 mm concrete cubes containing 0%, 1.5%, 3%, 5%, and 10% polystyrene. The test was conducted in compliance with ASTM C496 [33]. It determined the relationship between indirect tensile strength and polystyrene content. The indirect tensile strength was calculated using Equation (2).

$$f_c^t = (ZP)/\pi DL \quad (2)$$

Where: P - Load at break (Newtons), D - Cylinder area (mm²), L - Cylinder length (mm).

Figure 7 shows the placement of the concrete sample in the device for determining indirect tensile strength and the load application. It also shows the collapsed sample.

**Figure 7: Indirect Tensile Strength Test**

Table 9 presents the tensile strength for the control and modified concrete. Figure 8 shows that higher polystyrene contents reduce the concrete's tensile strength.

Table 9: Indirect Tensile Strength of the Concrete with Different Polystyrene Contents.

Mixture	Percentage of Polystyrene %	Indirect Tensile Strength (MPa)	
		After 7days	After 28 days
1	0	2.276	4.10
2	1.5	1.91	3.18
3	3.0	1.09	1.34
4	5.0	0.68	0.77
5	10	***	0.24

The sample were produced, cured, and tested in accordance with BS EN 12390-6.

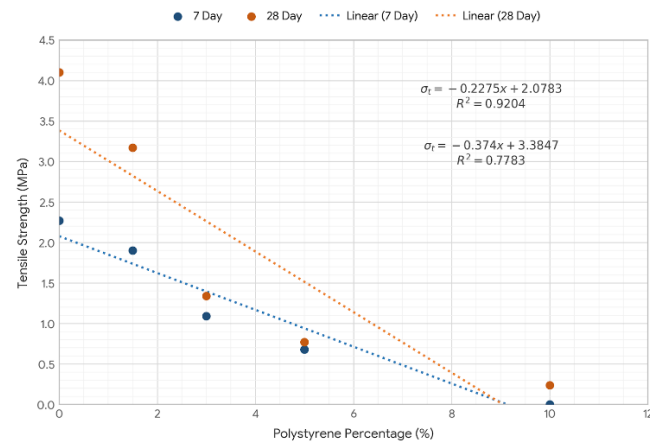


Figure 8: Plot of the Indirect Tensile Strength vs. Polystyrene Content

Relationship between Polystyrene, Density, and Compressive Strength

Figure 9 shows that lower compressive strength leads to lower density. Increasing the polystyrene content reduces the bulk density and compressive strength.

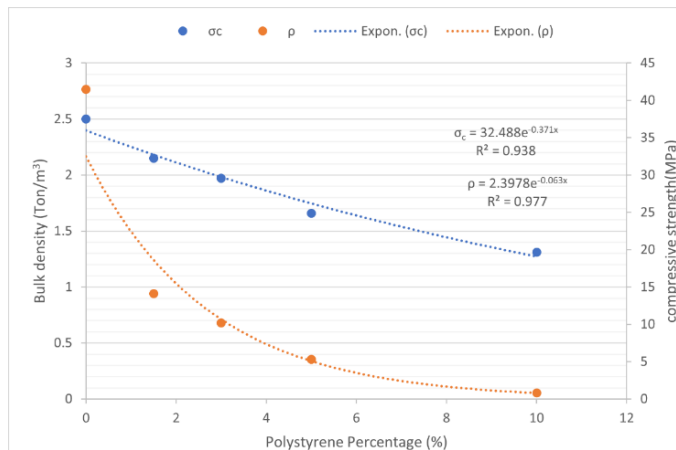


Figure 9: Relationship between Polystyrene, Compressive Strength, and Bulk Density.

The factors influencing compressive strength also affected the elasticity parameters to a lesser extent. Figure 10 describes the relationship between polystyrene content, modulus of elasticity, and compressive resistance. Table 10 presents compression resistance and modulus of elasticity calculated using the formula provided by the American Institute of Concrete.

$$Ec = \gamma_c^{1.5} \times 0.043 \sqrt{f_c} \quad (3)$$

Where: E_c - Modulus of elasticity (MPa). f_c = Compressive strength (MPa). $\gamma_c^{1.5}$ = Concrete density (Kg/m^3).

Table 10: Compressive Strength and Modulus of Elasticity of the Concrete Mixtures

Mixture	Percentage of Polystyrene	Compressive Strength (MPa) After 28 Days	Modulus of Elasticity (MPa)
1	0	41.47	1073.11
2	1.5	14.13	499.56
3	3.0	10.20	372.27
4	5.0	5.30	207.56
5	10	0.82	57.23

The cubes were produced, cured, and tested in accordance with BS

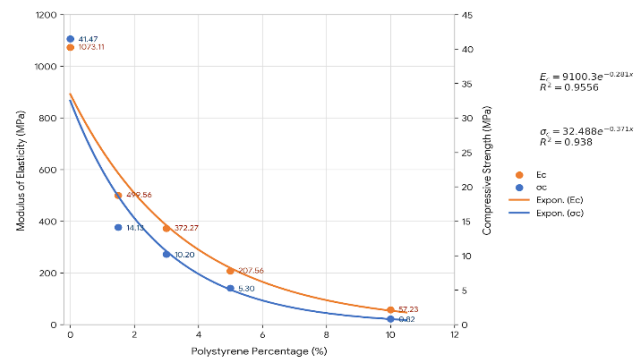


Figure 10: Relationship Between the Modulus of Elasticity, Compressive Strength, and Polystyrene Content.

Conclusions

This study conducted several tests to determine the mechanical and physical properties of the control and polystyrene-modified concretes. Based on the test results, it can be concluded that:

- Incorporating polystyrene into SCC altered its diffusion diameter and flow time. The flow diameter of most concrete samples was within the specified flow diameter of 650 mm to 800 mm. Higher polystyrene contents increased the viscosity and reduced the diameter spread. All samples, except the concrete sample with 10% polystyrene, had diffusion diameter and flow ability within the specified range.
 - The L-Box test showed that the flowability and filling ability of all concrete samples, except for the sample with 10% polystyrene, were within the specified limit when poured into densely reinforced sections with varying geometry.
 - The funnel (V-Funnel) test results were satisfactory and within the EFNARC limit.
 - Polystyrene altered the density of SCC, thereby affecting its mechanical and physical properties. Adding higher percentages of polystyrene by weight of cement reduced the density to between 2.50 ton/m³ and 1.31 ton/m³. However, incorporating 10% polystyrene by weight of cement reduced the density by 47.6%.
 - The compressive strength of SCC decreased systematically with increasing polystyrene replacement, dropping from 41.47 MPa in the control mix to 14.13 MPa (1.5% EPS) and 0.82 MPa (10% EPS) after 28 days of curing.
 - Although higher polystyrene contents reduced the compressive strength of SCC, the American Concrete Institute (ACI) guideline allows its utilization in certain non-load-bearing structural applications.
- This study has demonstrated the benefits of reusing environmentally harmful polystyrene-based industrial waste. Integrating polystyrene into LWC manufacturing is a viable approach to protecting the ecosystem.

Recommendation

Polystyrene is suitable for concrete works because it reduces their weight.

- Future studies should investigate the feasibility of replacing fine aggregates with different percentages of polystyrene
- Future studies should perform more rigorous evaluations to understand the behavior of polystyrene-modified concrete for structural applications, particularly thermal insulation.
- Natural resources are exhaustible. Therefore, global cooperation is imperative to conserving the environment and

preserving rare natural resources for future generations. One resource conservation approach is recycling plastic waste, including polystyrene, to conserve environmental assets. Recycling minimizes the landfill footprint and preserves the landscapes.

Author Contributions: Aldabar, Conceptualization, Methodology, Supervision, Writing – Original Draft Preparation; Arafa, Visualization, Data Curation, Investigation, Writing – Reviewing and Editing; Ali, Validation, Supervision, Writing – Reviewing and Editing; Elsheikh, Investigation, Resources, Data Curation; Al Dughhaishi, Supervision, Validation, Writing – Reviewing and Editing; Alosta, Methodology, Data Curation, Formal Analysis, Writing – Original Draft Preparation, Writing – Reviewing and Editing. All authors have read and agreed to the published version of the manuscript.

Funding: The authors declare that they have not received any funding support for the work reported in this paper.

Conflicts of Interest: "The authors declare no conflict of interest."

Data Availability Statement: "The data are available at request."

Acknowledgments: The authors would like to express their sincere appreciation to the University of Azzaytuna, Tarhuna, Libya; the Libyan Authority for Scientific Research, Tripoli, Libya; the Higher Institute of Science and Technology Aljufra (HIST), Sokna, Libya; and the University of Nizwa, Nizwa, Oman, for their financial support.

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