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Evaluation Performance of Structural Lightweight Self-Compacting Concrete Incorporating Two Type of Lightweight Aggregates Local Attapulgite versus LECA

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Abstract

The evolving need for environmentally friendly construction materials has led to the creation of lightweight self-compacting concrete (LWSCC). This overview examines the effect of lightweight coarse aggregate (LWCA) type on fresh and hardened properties of LWSCC, specifically evaluating the use of local lightweight Attapulgite aggregate (ATG) and comparing it with the conventional lightweight coarse aggregate, lightweight expanded clay aggregate (LECA). The study produced two LWSCC mixes with the same amount of binder and tested them using common methods for fresh and hardened properties, including slump flow, V-funnel, L-box, compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, and impact resistance. The results confirmed that each ATG- and LECA-based mix met the EFNARC requirements for fresh property and ACI limits for structural lightweight concrete (SLWC), which indicate that they can flow without vibrations and get compressive strength higher than 17 MPa. On the other hand, the flowability of the ATG mixtures was slightly lower because they absorbed extra water and had particles with angler edge, rough texture, and production method. Therefore, fresh properties have shown some increase when compared with LECA. LWSCCs primarily based on ATG had approximately 11% additional compressive strength and 21% better elasticity parameters than LECA mixtures. Furthermore, the overall performance in tensile, bending, and impact improved. The results show that ATG can be a viable alternative to conventional lightweight aggregates. This will help the environment and make the system perform better.

Keywords: Attapulgite, EFNARC, Impact Strength, LECA, Lightweight Self-Compaction Concrete.

1 Introduction

Concrete is the most prevalent construction material globally; nonetheless, its extensive usage of natural materials poses significant environmental and sustainability issues. The exhaustion of natural resources and the environmental consequences of aggregate extraction have led to significant investigation into alternative and recycled materials. Consequently, lightweight concrete (LWC) is present as a viable solution, providing diminished density, reduced dead loads, and decreased transportation and foundation costs. LWC is generally generated by substituting normal-weight aggregates with lightweight aggregates (LWA) or recycled materials [1], [2]. Besides sustainability factors, modern construction methods require concrete that exhibits better workability and self-compacting properties, especially for projects featuring dense reinforcement and complex engineering shapes. According to ACI 213R (2014) [3], structural lightweight concrete (SLWC) must achieve a minimum 28-day compressive strength of 17.2 MPa and an air-dry density ranging from 1440 to 1850 kg/m³. To meet both structural and workability requirements, lightweight self-compacting concrete (LWSCC) has been developed by integrating the advantages of LWC and self-compacting concrete (SCC) [4]. This material combines reduced self-weight with high flowability, excellent filling ability, and resistance to segregation.

On the other hand, the performance of LWSCC is significantly influenced by the properties of lightweight coarse aggregates (LWCA). Characteristics like particle shape, density, porosity, hardness, and surface texture have a significant impact on both fresh properties (like flowability, viscosity, and segregation resistance) and hardened properties (like strength, density, and interfacial transition zone (ITZ)) [5], [6], [7]. For instance, spherical aggregates like LECA tend to enhance the flowability and self-compaction better, whereas angular and denser aggregates like pumice tend to make mixture behave better mechanically, although this can come at the cost of workability [8]. Therefore, choosing and optimizing LWCA are very important for getting LWSCC to work well. Accordingly, a wide range of LWCAs has been investigated for structural lightweight concrete (SLWC), including lightweight expanded clay aggregate (LECA) [9], scoria [10], pumice stone [11], expanded polystyrene [12] and aggregates from industrial or mining waste [13], [14].

However, despite these advancements, the utilization of locally available materials remains limited, particularly in developing regions. This highlights the need to explore sustainable, region-specific alternatives that can reduce costs and environmental impacts while maintaining adequate performance. In this context, Attapulgite clay represents a promising material available domestically in Iraq, especially within the Al-Najaf and Karbala areas [15]. Previous studies have proved that it is possible to use Attapulgite aggregate for the production of SLWC [16], [17]. Using ATG in LWSCC offers economic and environmental benefits, along with reduction of environmental impact and carbon emissions associated with sustainable construction materials, reduced transportation cost, reduced structural load, and appropriate mechanical performance [18]. Razak et al. (2019) [19] stated that incorporating ATG to produce LWSCC resulted in equilibrium densities of 1868–1889 kg/m3 with adequate fresh properties and structural strength. Furthermore, the combination of specific types of LWCA has been shown to enhance the compatibility between functionality and mechanical performance [10], [11].

However, despite the promising findings, major study gaps remain. Existing research mainly focuses on conventional LWCA, including LECA, while local aggregates such as ATG have not been adequately investigated so far, especially in the framework of LWSCC.

Furthermore, the effect of LWCA properties on fresh concrete behavior, segregation resistance, mechanical, elastic, and impact performance under fixed mixing design conditions has not been systematically investigated. In particular, the impact resistance and elastic parameters of ATG-based fully LWSCC remain largely unexplored due to their structural importance for packages. Accordingly, this study is to examine the impact of artificial Attapulgite lightweight aggregate (ATG) on the performance of LWSCC and to assess its viability as a sustainable local substitute for a common type of LWCA. The research methodically investigates novel characteristics, mechanical strength, elastic modulus, and impact resistance. The results are expected to improve understanding of the function of LWCA in LWSCC and to facilitate the creation of sustainable, high-performance concrete from locally sourced resources.

2 Materials and Methods

2.1 Materials

Type I, ordinary Portland cement, fly ash (FA), natural sand (NS), water, superplasticizer (SP), and two types of lightweight coarse aggregate (LWCA). All materials were tested to verify compliance with relevant national and international standards. The cement (CMT) satisfied the requirements of (IQS-No.5, 2019) [20] in terms of chemical composition, fineness, soundness, setting time, and compressive strength. Fly ash (FA), class F, conforming to (ASTM-C618, 2022) [21], was used as a supplementary cementitious material. Natural sand from Al-Ekhaider region, classified as Zone II according to (IQS-No.45, 1984) [22], was used as fine aggregate, with physical and chemical properties within the specified limits. For coarse aggregate, two types used, Attapulgite lightweight aggregate (ATG), and lightweight expanded clay aggregate (LECA). Attapulgite clay, also known as Attapulgite and Palygoriskite, has two designations for this mineral. In 1940, Bradley [23] defined the term Attapulgite for the Attapulgus mineral originating from Georgia, U.S.A. Attapulgite is a fibrous silicate characterized by a large surface area and acidic properties, rendering the clay particularly effective as an adsorbent and a catalyst. Attapulgite develops on the Earth's surface in low-temperature conditions, so it is classified as clay [24]. Attapulgite clay is found in Iraq as bluish-green and white clay lumps in the Al-Najaf and Karbala districts (Tar Al-Najaf and Karbala regions). By using a hammer and jaw crusher, the rocks were crushed into smaller sizes, to give a finished product with a maximum size of about 12 mm. After that, the Attapulgite clay particles used as LWCA in the present study were fired at 1000 ˚C for half an hour following the procedure reported by (Hussein et al., 2015) [17], and (Abdul Sada et al., 2021) [16] to get ATG, Figure 1 shows the steps for producing ATG.

Fig. 1: Production Step of Attapulgite Lightweight Aggregates

While the other type has a commercial name known as LECA and imported from Iran, was used as a conventional LWCA. Both ATG and LECA satisfied the requirements of (ASTM-C127, 2017) [25] and (ASTM-C330, 2017) [26], respectively, and the results are shown in Table 1. Master Glenium® 54, used as a superplasticizer, is a high-range water-reducing admixture complying with (ASTM-C494/C494M, 2022) [27], Types F and G, and was used in all mixtures to achieve the required fresh properties. Overall, all materials were deemed suitable for the production of LWSCC.

Table 1: Lightweight Coarse Aggregate Properties

Properties	ATG	LECA	Specification	Allowable Limits
Bulk density (Kg/m^3)	750	400	ASTM C127	≤ 880
specific gravity (OD)	1.42	1.26	ASTM C127	≤ 2.6
Absorption %	27.9	18	ASTM C127	5 - 30

2.2 Mix Design

Two concrete mixtures, as shown in Table 2, were systematically designed to develop LWSCC. Water-to-binder ratios (W/Cm) of 0.32 and 0.30 were used for ATG- and LECA-based mixes, respectively, with a consistent binder content of 500 kg/m³. FA was incorporated at 25% by weight of cement for both LWCA types. SP dosages ranged from 1–1.5% by weight of binder to achieve target workability and flow, in accordance with (EFNARC, 2002 and 2005) [28],[29]. The experimental program aimed to produce structural lightweight self-compaction concrete (SLWSCC) using local LWCA which makes LWSCC mixture suitable to use in structure applications by reducing self-weight while maintaining high impact resistance and energy dissipation.

Table 2: Details of mixes by weight (kg/m3)

No.	Mix	Cement	Fly ash	Sand	LWCA	Water	SP %
1	ATG-C	380	120	747	432	160	1
2	LECA-C	380	120	650	450	150	1.33

2.3 Mixing

Since ATG and LECA have a high capacity for water absorption, they were submerged in water for 48 hours before being added to the mixture and then spread out in the laboratory [30], [31]. Then, the aggregate were used in the saturated surface dry (SSD) condition, which is recommended by the (ACI 211.2, 2004) [32], as shown in Figure 2. In this study, the mixing of reference concrete (LWSCC) using ATG or LECA was carried out in the same way. The method of (Al-Obaidey, 2015) [33] was used in the mixing of LWSCC. The following steps make up this method:

a) Cement and FA were mixed well before being added to the Mixer to make sure the mixture is very uniform.

b) The coarse and fine aggregates were added to the mixer along with one-thirds of the mixing water. The mixer was then turned on for a few turns.

c) The machine was then stopped so that the binder mixture could be added, and the rest of the water with SP was added.

d) The mixer was rotated for 3 minutes, rested covered for 3 minutes, and then spun covered for two more minutes.

e) After that, the fresh testing were conducted, as shown in **Figure 3** and then the mixture was placed in plastic mold and cured in a water tank for 28 days, as shown in **Figure 4**.

Fig. 2: Air Dry before Mixing for (A) ATG (B) LECA

2.4 Fresh Concrete Tests

To assess the fresh properties of LWSCC, a series of workability tests were carried out in accordance with reference [28] guidelines. The tests included the slump flow test, which measured concrete's horizontal flow and resistance to segregation, the V-funnel test, which assessed viscosity and resistance to segregation, the L-box test, which assessed flow and passing ability through confined spaces, and the V-funnel after five minutes (VFT5) test, which assessed filling ability and resistance to segregation.

(EFNARC, 2005) [29] and (EFNARC, 2002) [28] set broad acceptance requirements for LWSCC workability testing as shown in Table 3 and Figure 3, such as slump flow, T50, V-funnel, L-box, and segregation resistance. These characteristics ensure that LWSCC meets all three structural performance requirements: filling ability, passing ability, and segregation resistance.

Table 3: Typical Acceptance Criteria for SCC according to [28]

SI. No.	Property	Test Methods	Unites	Min.	Max.
1	Filling ability	Slump Flow	mm	650	800
		T_{500mm} Slump	sec	2	5
		V-Funnel	sec	6	12
2	Passing ability	L-Box	h2/h1	0.8	1
		U-Box	(h2-h1) mm	0	30
		J-Ring	mm	0	10
3	Segregation resistance	V-Funnel at 5 minutes	sec	6	15

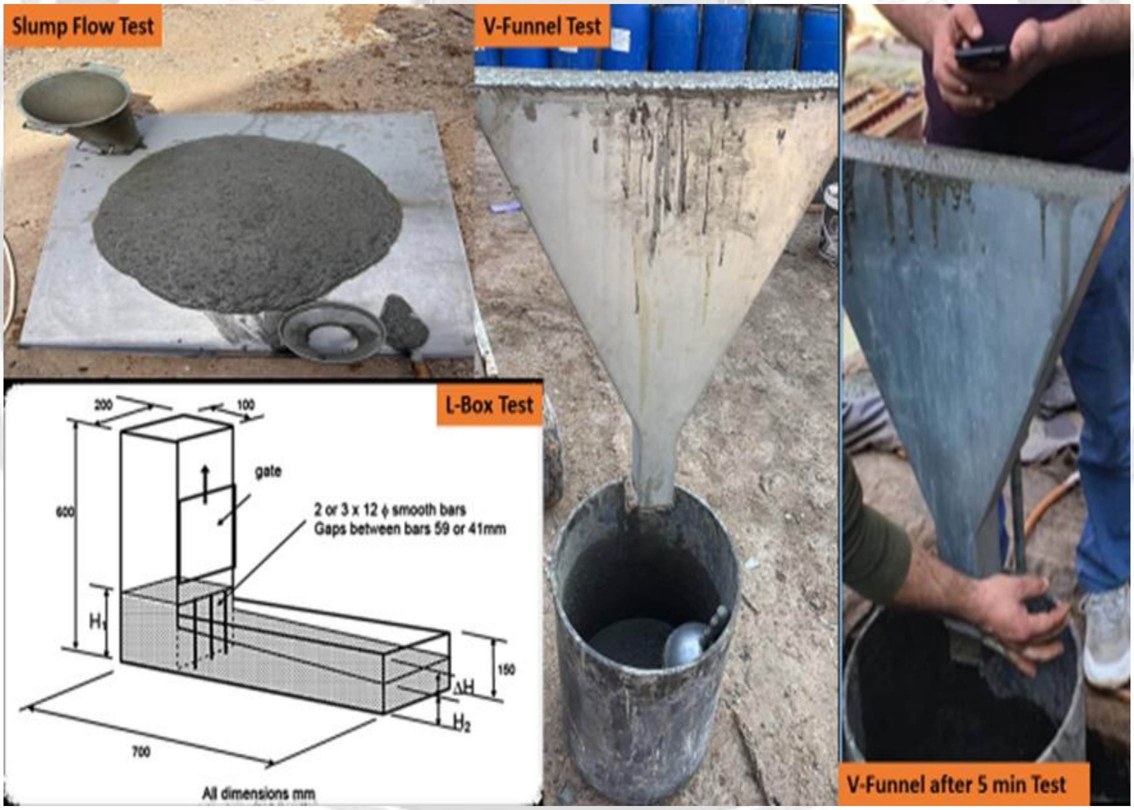

Fig. 3: Fresh Testing for LWSCC mixes

Fig. 4: Casting and Curing of LWSCC mixture

2.5 Hardened Tests

2.5.1 Compressive strength

According to (BS EN 12390, 2003) [34], the compressive strength test is carried out using 100mm cubes. The testing was done at 28 days and the average of three specimens was adopted.

2.5.2 Splitting tensile strength

The test is performed according to (ASTM C496/C496M, 2014) [35], using 100×200 mm cylindrical specimens. The specimens are tested at an age of 28 days and the average of three specimens was adopted.

2.5.3 Flexural tensile strength

Using prismatic concrete specimens of dimensions 100×100×400mm, and according to (ASTM C78/C78M, 2018) [36] the test was conducted. The specimens are tested at an age of 28 days and the average of three specimens was adopted.

2.5.4 Static modulus of elasticity

The static modulus was obtained according to (ASTM C469, 2004) [37]. Cylinders of (100x200) mm were used. However, before starting the test, the upper surface of the cylinder was smoothed and finished well to minimize friction between the sample surface and the testing machine. All tests were conducted at the ages of 28 days, and the average of three readings obtained from the samples was recorded.

2.5.5 Impact strength test

The conducted impact test was the drop-weight test, following the procedure recommended by (ACI 544.1, 2018) [38] using half-cylinders with dimensions of (65 x 150) mm. The test method adopted in the present work is based on previous research by (Mazen & Al-Mutairee, 2022) [39] and is shown in Figure 5, where a standard, manually operated 4.54 kg compaction hammer with a drop height of 457 mm and a hardened steel ball with a diameter of 63.5 mm was dropped onto the concrete sample, and the operation was repeated until the first crack appeared, which was recorded as (N1) and the specimens were continuously impacted until failure, with the number of impacts recorded as (N2).

The test was conducted at 28 days and the average of three specimens was adopted to ensure accurate results. For this study, the impact ductility ratio (IDR) was calculated (defined as □2: number of hits caused failure / N1: number of hits to notice first visible crack) to evaluate the ability of concrete to sustain impact loading after first cracking.

3 Results and Discussion

3.1 Fresh Properties

Table 4 summarized the fresh properties of LWSCC mixtures and discussed in the following subsections in accordance with [28], [29] acceptance criteria.

Table 4: Results of LWSCC Fresh Properties

No.	Mix	Slump flow (mm)	T_{500mm} (sec)	VF (sec)	VFT5 (sec)	L-Box
1	ATG-C	733	3	8	11.5	0.98
2	LECA-C	744	2.5	7	10	1

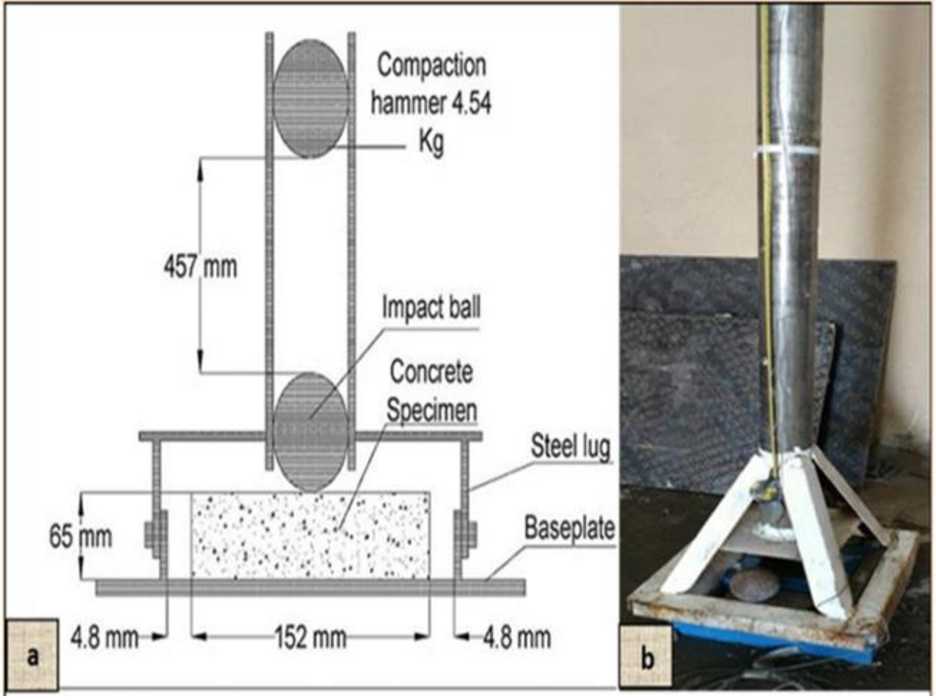

Fig. 5: Impact resistance machine

3.1.1 Slump flow

The slump flow values of the ATG-based LWSCC mixtures and those of the LECA-based mixtures ranged between 730 and 750 mm (Table 4). All result satisfied the EFNARC criteria, confirming adequate filling ability and deformability without segregation or bleeding.

The LECA mixture (LECA-C) showed higher slump flow than the ATG mixture (ATG-C), which is due to LECA's more spherical particle shape and smooth surface texture, which reduces internal friction. The type of LWCA has a significant effect on the flowability of LWSCC, where ATG significantly reduced flowability due to the angler shape of the aggregate particles. Despite this reduction, all mixtures conformed to acceptance criteria, indicating that suitable mix optimization can maintain self-compacting performance, as shown in Figure 6.

3.1.2 Flow time

The flow time (T50) results shown in Table 4 shows that all the mixes meet the EFNARC acceptance criteria, as shown in Table 3. The ATG mix shows a slightly longer T50 time of approx. 20% compared to the LECA control mixture, indicating variation due to different rheological properties between the two types of aggregates, as shown in Figure 7.

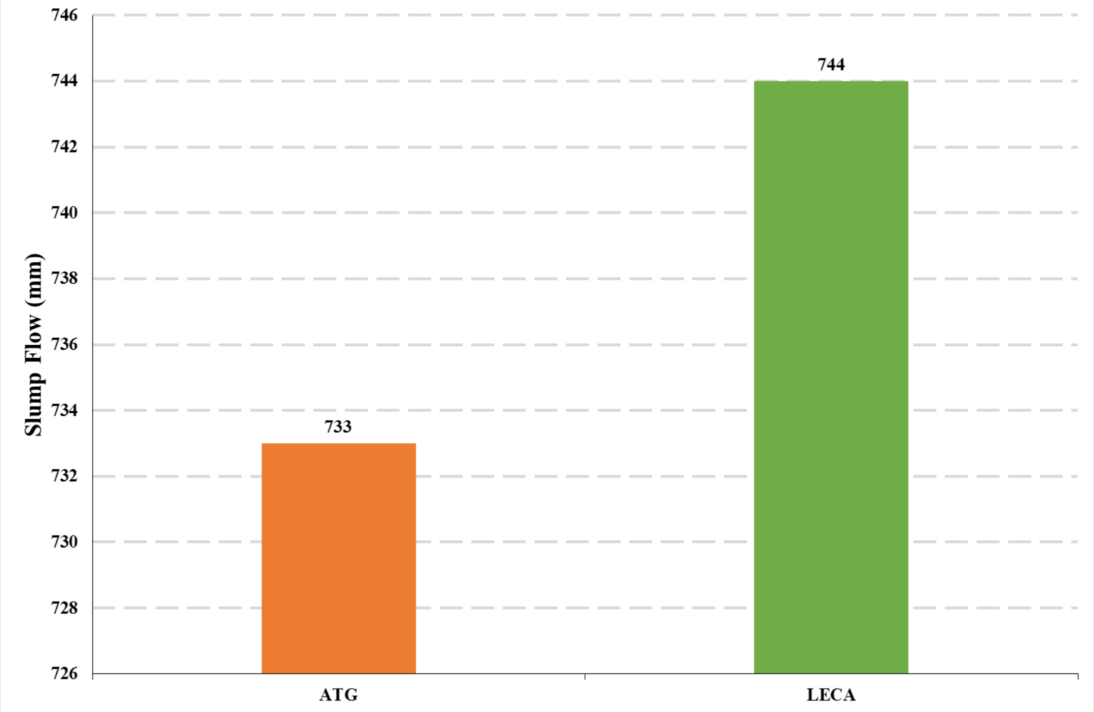

Fig. 6: Slump flow values of LWSCC mixes incorporating ATG and LECA

3.1.3 V-funnel

The V-funnel flow time (VF) presented in Table 4 satisfies EFNARC standards. ATG-based mixtures showed longer VF duration than LECA-based mixtures, which is due to higher porosity, angular morphology and water absorption of ATG, which increases the internal friction and viscosity of the mixtures. In contrast, LECA enabled more efficient particle movement and reduced flow time, as shown in Figure 7.

3.1.4 V-funnel after five minutes

The V-Funnel after 5 minutes (VFT5) test indicates segregation resistance and viscosity stability. ATG-based mixtures exhibited higher VFT5 values compared to LECA-based mixtures by about 15%, attributable to enhanced water absorption and diminished paste availability, as shown in Figure 7.

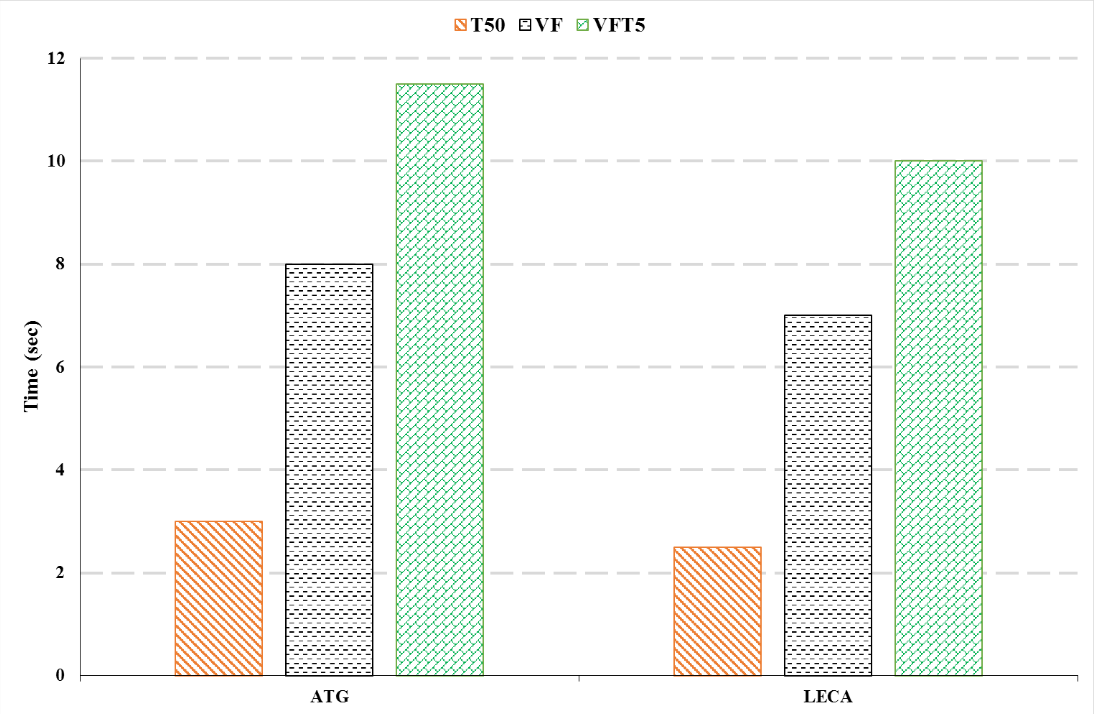

Fig. 7: T50, VF, and VFT5 of LWSCC mixes incorporating ATG and LECA

3.1.5 L-Box ratio

Table 4 shows that the L-box blocking ratios of all the mixtures were between 0.80 and 1.00. This means that they met EFNARC standards and showed that they were able to pass through heavy reinforcement members. ATG-based mixtures had lower blocking ratios than LECA-based mixtures because the rough surface roughness and higher absorption of ATG and the behavior of SP with spherical shape of LECA particle improved the flowability of the mixture compared with ATG during flow in mold.

3.2 Hardened Concrete Properties

The hardened properties at 28 days are presented in Table 5 and discussed below:

Table 5: Results of LWSCC Hardened Properties @ 28 day

No.	Mix	Comp. (MPa)	Split. (MPa)	Flex. (MPa)	E (GPa)	IDR
1	ATG-C	35	3.5	3.36	24.2	1.73
2	LECA-C	31.5	2.88	2.84	20	1.57

3.2.1 Compressive strength

The 28-day compressive strength results (Table 5 and Figure 8) confirm that all mixtures satisfied the minimum strength requirement for SLWC specified by (ACI 213R, 2014) [3]. The ATG control mixture exhibited approximately 11% higher compressive strength than the LECA control mixture, which is attributed to the higher stiffness, angular shape, and stronger interfacial bonding of ATG particles with the cement paste and comfort with reference [15], regarding the use of ATG in structural applications.

3.2.2 Splitting tensile strength

The splitting tensile strength results (Table 5 and Figure 8) show that ATG-based control mixtures achieved higher tensile strength than LECA-based mixtures by about 21.53%, consistent with the compressive strength factors and also with SLWC limitations.

3.2.3 Flexural tensile strength

Table 5 and Figure 8 display the outcomes of the flexural tensile strength assessments. The results demonstrate that the ATG-based mixtures displayed higher flexural strength relative to the LECA-based mixtures, with an enhancement of roughly 18%. This increase aligns with the observed trends in both compressive strength and splitting tensile strength, indicating a uniform improvement in the overall mechanical performance of ATG-based mixes.

The superior flexural performance of the ATG mixtures can be attributed to the stronger interfacial bond between the aggregate and the cement matrix, as well as the higher intrinsic strength of the aggregate itself. In contrast, the relatively lower strength of LECA particles results in reduced resistance under flexural loading conditions. Furthermore, in lightweight concrete (LWC), the failure mechanism is characterized by crack propagation through LWCA, rather than along the interfacial transition zone (ITZ) or through the cement paste. This behavior indicates that the LWCA particles constitute the weakest phase in the composite system and therefore govern the overall failure process. Despite this limitation, the observed performance remains adequate, suggesting that such materials can still be effectively utilized in structural applications.

3.2.4 Static modulus of elasticity

Table 5 reviews the static modulus of elasticity (EC) results, while Figures 8 illustrates them. The result shown that the ATG-based mixtures show approximately 21% higher modulus values than the LECA-based mixtures. The difference can be attributed to the higher hardness and toughness of the ATG aggregates as well as their improved ITZ quality, and the higher compressive strength.

3.2.5 Impact ductility ratio

The impact ductility ratio (IDR) results (see Table 5 and Figure 8) show that ATG-based mixtures have higher ductility than LECA-based mixtures due to better aggregate interlock and progressive fracture development. Moreover, the final shape of specimen after failure can be seen in Figure 9, which show that LECA more crushed than ATG.

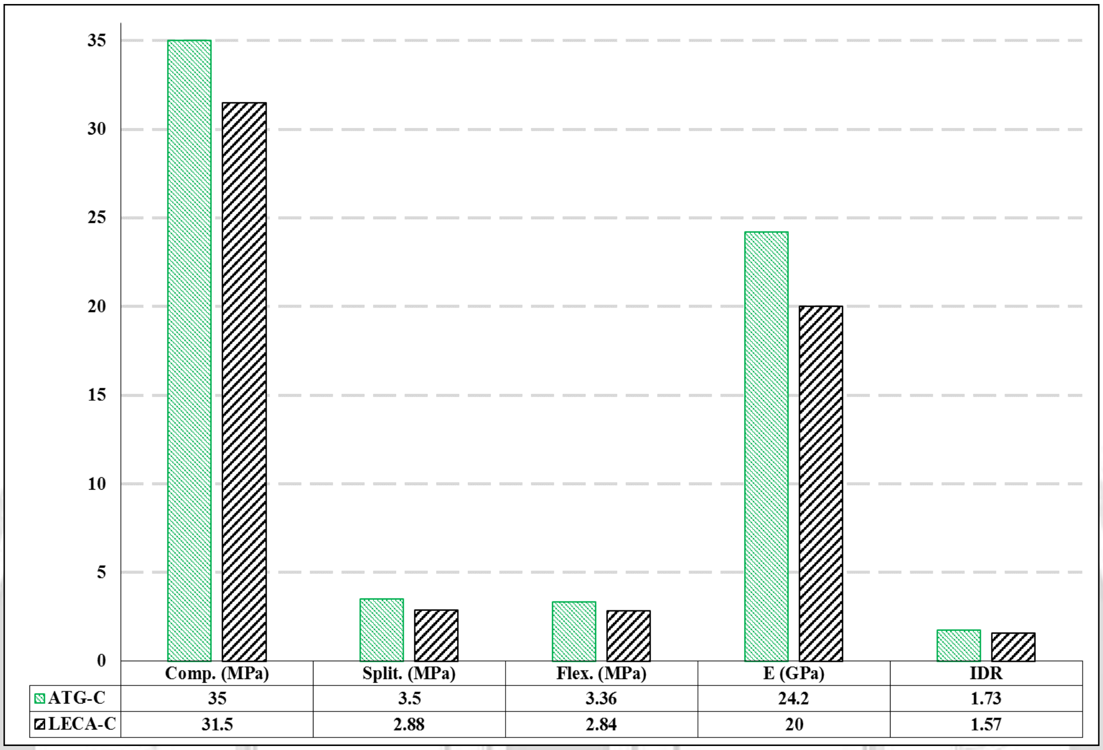

Fig. 8: Hardened Properties of LWSCC Using Different of LWCA Types

Fig. 9: Impact specimens after failure

4 Conclusions

Based on the experimental results obtained in this study, the following conclusions can be drawn:

- Both ATG- and LECA-based lightweight self-compacting concrete (LWSCC) mixtures satisfied the EFNARC requirements for self-compacting concrete and achieved the strength requirements of structural lightweight concrete (SLWC).
- The ATG-based mixture exhibited slightly lower flowability than the LECA-based mixture, with a 1.5% reduction in slump flow and a 20% increase in T50 flow time, mainly due to its angular particle shape, rough surface texture, and higher water absorption. Nevertheless, all fresh properties remained within the acceptable EFNARC limits.
- The use of ATG significantly improved the mechanical performance of LWSCC. Compared with the LECA mixture, the ATG mixture achieved approximately 11.1% higher compressive strength, 21.5% higher splitting tensile strength, and 18.3% higher flexural strength.
- The modulus of elasticity of the ATG mixture was approximately 21% higher than that of the LECA mixture, indicating improved stiffness and a stronger aggregate–paste interaction.
- The impact ductility ratio (IDR) increased from 1.57 for the LECA mixture to 1.73 for the ATG mixture, representing an improvement of approximately 10.2%. This result demonstrates the superior ability of ATG-based LWSCC to absorb impact energy and sustain loading after first cracking.
- The enhanced mechanical, elastic, and impact performance of the ATG mixture is attributed to the higher stiffness, angular geometry, and stronger interfacial bonding of the ATG particles with the cementitious matrix.
- The findings confirm that locally produced Attapulgite aggregate (ATG) is a promising and sustainable lightweight aggregate that can successfully replace conventional LECA in the production of structural lightweight self-compacting concrete.

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Author Contributions

Ali H. Nahhab planned the experiments, analyzed the data, supervised the experimental work, and contributed to the review and editing. Mohammed J. Kadhim contributed to review, and editing. Mustafa S. Hamdi conducted the experiments and wrote the original manuscript.

Statement of Conflicting Interests

The authors declare that they possess no identifiable competing financial interests or personal ties that may have apparently influenced the work presented in this study. All authors have examined the final version of the work and endorse its submission. This work has no conflicts of interest concerning funding, authorship, or publishing.

Data Availability

Data will be made available on request.

Research Funding

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Ethics statement

Ethics, Consent to Participate, and Consent to Publish: Not applicable

5 References

[1] A. Gerritse, “Design considerations for reinforced lightweight concrete,” *Int. J. Cem. Compos. Lightweight Concr.*, vol. 3, no. 1, pp. 57–69, 1981, doi: https://doi.org/10.1016/0262-5075(81)90031-2.

[2] Ola Mazen Makki, “Heat influence on sustainable rubberized concrete mixes,” *Res. Eng. Struct. Mater.*, 2025, doi: 10.17515/resm2025-400ma0116rs.

[3] ACI 213R, “ACI Committee for Structural Lightweight Aggregate Concrete,” American Concrete Institute, Farmington Hills, MI, USA, 2014.

[4] Wafaa Hussein Al-Kabi and Hadeel Khalid Awad, “Investigating Some Properties of Hybrid Fiber Reinforced LECA Lightweight Self-Compacting Concrete,” *J. Eng.*, vol. 30, no. 03, pp. 177–190, Mar. 2024, doi: 10.31026/j.eng.2024.03.12.

[5] J. A. Bogas, A. Gomes, and M. F. C. Pereira, “Self-compacting lightweight concrete produced with expanded clay aggregate,” *Constr. Build. Mater.*, vol. 35, pp. 1013–1022, Oct. 2012, doi: 10.1016/j.conbuildmat.2012.04.111.

[6] M. C. S. Nepomuceno, L. A. Pereira-de-Oliveira, and S. F. Pereira, “Mix design of structural lightweight self-compacting concrete incorporating coarse lightweight expanded clay aggregates,” *Constr. Build. Mater.*, vol. 166, pp. 373–385, Mar. 2018, doi: 10.1016/j.conbuildmat.2018.01.161.

[7] K. Siamardi, “Optimization of fresh and hardened properties of structural light weight self-compacting concrete mix design using response surface methodology,” *Constr. Build. Mater.*, vol. 317, p. 125928, Jan. 2022, doi: 10.1016/j.conbuildmat.2021.125928.

[8] İ. Topçu and T. Uygunoğlu, “Effect of aggregate type on properties of hardened self-consolidating lightweight concrete (SCLC),” *Constr. Build. Mater.*, vol. 24, pp. 1286–1295, Jul. 2010, doi: 10.1016/j.conbuildmat.2009.12.007.

[9] R. Gopi and V. Revathi, “Flexural behavior of self compacting self curing concrete with lightweight aggregates,” *Mater. Today Proc.*, vol. 45, pp. 2449–2455, 2021, doi: 10.1016/j.matpr.2020.11.019.

[10] A. Sadrmomtazi and H. P. S. Arabani, “On Fresh and Hardened Properties of Lightweight Self-Compacting Concrete,” *Int. J. Eng.*, vol. 38, no. 4, pp. 767–784, 2025, doi: 10.5829/ije.2025.38.04a.09.

[11] J. H. Baban, B. O. Taha, and G. J. Khoshnaw, “Fresh Properties of Lightweight Concrete and Lightweight Self Compacting Concrete Produced with Pumice Aggregate,” *Eurasian J. Sci. Eng.*, vol. 6, no. 2, 2020, doi: 10.23918/eajse.v6i2p11.

[12] Guilherme S. Araujo, Lui C. Iwamoto, Rosa C. C. Lintz, and Luisa A. Gachet, “Influence of Incorporation and Dimension of Expanded Polystyrene on Lightweight Concrete,” *ACI Mater. J.*, vol. 118, no. 1, Jan. 2021, doi: 10.14359/51728280.

[13] S. S. Vivek, “Performance of ternary blend SCC with ground granulated blast furnace slag and metakaolin,” *Mater. Today Proc.*, vol. 49, pp. 1337–1344, 2022, doi: 10.1016/j.matpr.2021.06.422.

[14] B. C. Xavier, A. E. Gomes, M. L. Melo, R. C. C. Lintz, L. A. Gachet, and W. R. Osório, “Study of three distinct self-compacting concretes containing marble/granite powder and hooked-end steel fiber contents,” *J. Compos. Mater.*, vol. 55, no. 20, pp. 2823–2838, Aug. 2021, doi: 10.1177/0021998321999438.

[15] J. F. Qais, A. A. Waleed, and J. H. Mahdi, “Producing Lightweight Concrete Aggregate from Iraqi Attapulgite,” *Proc. Int. Struct. Eng. Constr.*, vol. 1, no. 1, Nov. 2014, doi: 10.14455/isec.res.2014.132.

[16] Y. A. Abdul Sada, L. Sh. Rasheed, and R. Al-Mahaidi, “The combined effect of lightweight coarse aggregate and steel fibers on the mechanical properties of concrete,” *J. Phys. Conf. Ser.*, vol. 1973, no. 1, p. 012223, Aug. 2021, doi: 10.1088/1742-6596/1973/1/012223.

[17] Mahdi Hussein, Qais Frayyeh, and Waleed A. Abbas, “Producing Concrete Lightweight Aggregate from Iraqi Attapulgite Clay,” presented at the Sustainable Solutions in Structural Engineering and Construction, 2nd, Jun. 2015.

[18] S. Adhikary *et al.*, “Lightweight self-compacting concrete: A review,” *Resour. Conserv. Recycl. Adv.*, vol. 15, p. 200107, Jul. 2022, doi: 10.1016/j.rcradv.2022.200107.

[19] W. Razaq, Q. Freih, and S. Al Obaidey, “The Effect of Using Multi Types of Mineral Admixtures on Some Properties of Lightweight Self-Compacting Concrete,” *Eng. Technol. J.*, vol. 37, no. 1C, pp. 186–194, Apr. 2019, doi: 10.30684/etj.37.1C.29.

[20] IQS, No. 5, *Iraq Standard Specification (IQS) No.5, in Portland Cement*, Baghdad -Iraq., 2019.

[21] ASTM C618, *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete*, West Conshohocken, PA., 2022.

[22] IQS No. 45, *Aggregate from Natural Sources for Concrete and Construction*, Baghdad - Iraq., 1984.

[23] W. F. Bradley, “The Structure Scheme of Attapulgite,” *Am. Mineral.*, vol. 25, no. 6, pp. 405–410, 1940.

[24] F. Altun and B. Aktaş, “Investigation of reinforced concrete beams behavior of steel fiber added lightweight concrete,” *Constr. Build. Mater.*, vol. 38, pp. 575–581, Jan. 2013, doi: 10.1016/j.conbuildmat.2012.09.022.

[25] ASTM C 127, *Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate*, West Conshohocken, PA, United States., 2004.

[26] ASTM C330, *Standard Specification for Lightweight Aggregates for Structural Concrete*, West Conshohocken, PA., 2017.

[27] ASTM C494, *Standard Specification for Chemical Admixtures for Concrete*, ASTM C494-22, West Conshohocken, PA., 2022.

[28] EFNARC LIMIT, “The Specification and Guidelines for Self-Compacting Concrete,” European Federation for Specialist Construction Chemicals and Concrete Systems, Norfolk, UK, Feb. 2002.

[29] EFNARC, “the European Guidelines for Self Compacting Concrete: Specification, Production and Use,” European Federation of Specialist Construction Chemicals and Concrete Systems, Norfolk, UK, 2005.

[30] Shubbar J. KadhumAl-Obaidey, “The Effects of Maximum Attapulgite Aggregate Size and Steel Fibers Content on Fresh and Some Mechanical Properties of Lightweight Self Compacting Concrete,” *J. Eng.*, vol. 26, no. 5, pp. 172–190, May 2020, doi: 10.31026/j.eng.2020.05.12.

[31] A. H. Nahhab and A. K. Ketab, “Influence of content and maximum size of light expanded clay aggregate on the fresh, strength, and durability properties of self-compacting lightweight concrete reinforced with micro steel fibers,” *Constr. Build. Mater.*, vol. 233, p. 117922, Feb. 2020, doi: 10.1016/j.conbuildmat.2019.117922.

[32] ACI 211.2, “Standard Practice for Selecting Proportions for Structural Lightweight Concrete,” American Concrete Institute, Farmington Hills, Michigan, U.S.A, ACI 211.2, 1998.

[33] Al-Obaidey Shubbar Jawad Kadhum, “Fresh and Some Hardened Properties of Lightweight Self Consolidating Concrete Containing Attapulgite,” Ph.D. Thesis, University of Technology, Baghdad -Iraq, 2015.

[34] BS EN 12390, *BS EN 12390-3: Testing hardened concrete – Compressive strength of test specimens*, London., 2003.

[35] ASTM C496/C496M, *Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens*, Philadelphia, PA, USA., 2014.

[36] ASTM C78/C78M, *Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)*, ASTM C78/C78M-18, West Conshohocken, PA., 2018.

[37] ASTM C 469, *Standard Test Method for Static Modulus of Elasticity and Poisson’s Ratio of Concrete in Compression*, Philadelphia, PA, USA., 2004.

[38] ACI 544.1, “ACI Committee to design with fiber-reinforced concrete,” American Concrete Institute, Farmington Hills, Michigan, 2018.

[39] O. M. Makki and H. Al-Mutairee, “Mechanical and Dynamical Properties of Structural Rubcrete Mixes,” *Int. J. Eng.*, vol. 35, pp. 1744–1751, Sep. 2022, doi: 10.5829/ije.2022.35.09C.10.

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تقييم أداء الخرسانة الانشائية خفيفة الوزن ذاتية الرص باستخدام نوعين من الركام خفيف الوزن: ركام الأتبولجيات المحلي مقارنة مع الركام الطيني الخفيف الوزن (الليكا)

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الخلاصة

أدى تزايد الحاجة إلى مواد بناء صديقة للبيئة إلى ابتكار الخرسانة خفيفة الوزن ذاتية الدمك (LWSCC). تتناول هذه الدراسة تأثير نوع الركام الخشن خفيف الوزن (LWCA) على خصائص الخرسانة خفيفة الوزن ذاتية الدمك في حالتيها الطرية والمتصلبة، مع التركيز على تقييم استخدام ركام الأتابولجيت المحلي خفيف الوزن (ATG) ومقارنته بنوع الركام الخفيف الخشن التقليدي المعروف، وهو ركام الطين المتمدد خفيف الوزن او مايسمى (LECA). أُجري البحث على خلطتين من الخرسانة خفيفة الوزن ذاتية الدمك بنفس كمية المادة الاسمنتية، وتم اختبارهما باستخدام الطرق الشائعة لقياس خصائص الخرسانة الطرية والمتصلبة، بما في ذلك اختبار الهبوط، واختبار القمع V، واختبار L–Box، واختبار مقاومة الانضغاط، ومقاومة الشد، ومقاومة الانحناء، ومعامل المرونة، ومقاومة الصدم. أكدت النتائج أن كلتا الخلطتين، سواءً المعتمدة على ركام الأتابولجيت أو ركام الطين المتمدد خفيف الوزن، تستوفيان متطلبات الاتحاد الأوروبي للخرسانة الوطنية الأمريكية (EFNARC) للخصائص الطرية، وحدود معهد الخرسانة الأمريكي (ACI) للخرسانة الإنشائية خفيفة الوزن (SLWC)، مما يشير إلى قدرتهما على التدفق دونا لحاجة الى اهتزازات الرص وتحقيق مقاومة ضغط أعلى من 17 ميجا باسكال. من ناحية أخرى، كانت سيولة خلطات ATG أقل قليلاً بسبب امتصاصها كمية إضافية من الماء، واحتواء جزيئاتها على حواف مائلة، وملمس خشن، وطريقة إنتاجها. ولذلك، أظهرت خصائصها في حالتها الطرية تحسناً طفيفاً مقارنةً بخلطات LECA. وقد أظهرت الخرسانة خفيفة الوزن المعتمدة بشكل أساسي على ATG مقاومة انضغاط إعلى بنسبة 11% تقريباً، ومعامل المرونة أفضل بنسبة 21% مقارنةً بخلطات LECA. علاوة على ذلك، تحسن الأداء العام في اختبارات الشد والانحناء والصدم. تشير النتائج إلى أن ATG يمكن أن يكون بديلاً فعالاً للركام الخفيف الوزن التقليدي، مما يُسهم في حماية البيئة وتحسين أداء النظام الانشائي.

الكلمات الدالة: اتبلغايت، افنارك، مقاومة الصدم، ليكا، خرسانة خفيفة ذاتية الرص.