Engineering and Technology Journal 41 (05) (2023) 734-744

Engineering and Technology Journal
Journal homepage: https://etj.uotechnology.edu.iq

Fresh Properties of Self-Consolidating Expired Cement-Fly Ash Cold Bonded Lightweight Aggregate Concrete With Different Mineral Admixtures

Haider Araby Ibrahim*, Waleed A. Abbas

Civil Engineering Dept., University of Technology- Iraq, Alsina'a street, 10066 Baghdad, Iraq.
*Corresponding author Email: bce.20.11@grad.uotechnology.edu.iq

HIGHLIGHTS

- EC can be recycled in ALA.
- Reducing the cost of SCLC with ALA.
- Improved the fresh properties of SCLC with SF, FA and ALA.

ARTICLE INFO

Handling editor: Mahmoud S. Al-Khafaji

Keywords:
Expired cement
Cold bonding
Fresh properties
Self-consolidating lightweight concrete
Silica fume
Fly ash

ABSTRACT

The experimental program evaluated the fresh properties of self-consolidating lightweight concretes (SCLC) produced from expired cement EC cold-bonded lightweight coarse aggregates (ALA) with silica fume (SF) and fly ash (FA). Twelve mixtures of SCLC were prepared, the binder in the control mix was just Portland cement (PC), whereas other mixes included binary and ternary of (PC), 20% of (FA), and/or (10%) of (SF) with (0%, 50%, and 100%) as partial replacement of (ALA) with coarse natural aggregates. Fresh features of (SCLC) were evaluated by measuring their slump flow diameter, T500 slump flow time, V-funnel flow time L-box height ratio, and column segregation, (SCLC) with and without mineral admixtures have their fresh characteristics compared. It was found that increasing the quantity of ALA replacement resulted in a reduction in the amount of superplasticizer required to obtain a constant slump flow diameter of SCLC. Combining (SF) and/or (FA) lowered both the V-funnel flow time and the slump flow time, whereas the L-box height ratio increased from (0.82) to (0.*86)* with the addition of fly ash for reference mix. With the combined action of mineral admixtures, the percentage of column segregation decreases by (16.7%) compared with the reference mix. The maximum slump flow was (792) mm with a mix of (M6).

1. Introduction

A ton of cement emits about 900 kg of CO_2; this equals 5% of global emissions [1]. There is 80% pollution from firing and 10% pollution from grinding [2]. Unused or improperly kept cement will expire if not used within the recommended storage term and can be considered waste material. Expired cement is the cement that has been used after its expiration date, which can be anywhere from (3-6) months. It is possible for cement to partially hydrate when stored due to moisture penetration. This means that when the cement finally mixed and used, it will have less hydration capacity [3].

Environmental and economic parameters have significantly influenced the manufacturing of artificial lightweight aggregates (ALA) from waste material, as well as improved performance attributes due to growing interest in and demand for waste product recycling [4]. There are many advantages to utilizing waste materials in the production of ALA. Without the use of natural aggregates, natural resources are not depleted, and hazardous aggregate mining activities are avoided. Waste aggregates can be lighter than natural aggregates, resulting in lightweight concrete. Furthermore, greenhouse gas emissions are lowered as the demand for large quantities of cement declines [5].

In general, there are main three processes for producing artificial aggregate sintering, autoclaving, and cold bonding. Sintering is a common method for producing lightweight artificial aggregate. Cold bonding is considered highly cost-effective due to its low energy consumption, whereas sintering had to be terminated due to its high energy consumption and environmental impact. Energy resources have been exhausted in recent years [6].

When normal aggregate (NA) is completely replaced by ALA, concrete workability improves significantly [7]. This is primarily due to the spherical shape of ALA as opposed to the angular features of NA [8]. To obtain the same artificial

http://doi.org/10.30684/etj.2023.139260.1424
Received 25 March 2023; Accepted 13 May 2023; Available online 25 May 2023
2412-0758/University of Technology-Iraq, Baghdad, Iraq

lightweight concrete (ALAC) workability, the normal aggregate concrete (NAC) mixture should be adjusted, either by increasing the cement paste volume or the amount of superplasticizer, but this increases the cost [3]. Kockal and Ozturan discovered that when NA was replaced with ALA, the amount of superplasticizer needed to obtain the required slump decreased by roughly 8% [9]. Additionally, it has been found that the ALA content affects how well ALAC functions. Increased ALA volume content has been observed to greatly alleviate the ALAC slump [10]. Increasing the amount of ALA, which has a rounded form and smoother surface, lowers friction between aggregate particles and cement paste, resulting in significantly improved concrete flowability [11]. The explanation above makes it very evident that ALAC has better fresh characteristics than NAC, and that using dry ALA with a saturated surface can actually enhance these properties. Because less superplasticizer is needed to obtain the desired workability, the use of ALA in concrete can therefore be cost-effective.

The incorporation of cold bonding aggregate (CBA) has been found to alter the fresh density of concrete since the fresh density of concrete is correlated with the density of its constituents. Tang and Brouwers [12] have found that when NA is substituted with CBA, at replacement levels of 30% and 60% by volume, respectively, the fresh density of NAC reduces by roughly 5% and 8%, the fresh density of CBAC was determined to be 17% lower than that of NAC [13].

Concrete with self-compacting lightweight aggregates (SCLC) combines the advantages of self-compacting concrete with the advantages of lightweight aggregate concrete. This means (SCLC) are a type of high-performance concrete that can be cast in place, consolidated, and pass through crowded reinforcements. It can also fill complex shapes without segregation or bleeding [14,15].

Many researchers investigated the use of CBA in the production of self-consolidation concrete (SCC). The European Federation of Specialist Construction Chemical and Concrete System (EFNARC) [16] standards are used to define SCC based on its flowability, viscosity, and ability to pass testing using the Slump flow, T50, V-funnel, and L-box tests. Gesogˆlu et al. [17] have reported that replacing 100% NA by volume with CBA improves the fresh properties of SCC significantly, with the amount of superplasticizer required decreasing from 8 to 4.2 kg/m3, slump flow increasing from 700 to 750 mm, and T50 and V-funnel decreasing from 3.43 to 1 s and 17.22 to 5.13 s, respectively. This trend is consistent with findings from other investigations [12, 18]. Topçu and Uygunog˘lu [19] found that incorporating lighter particles increased the diameters of self-consolidating concrete slump flow. SCLC containing 100% LWAs were approximately 25% lighter per unit volume than the control mix including 100% normal-weight aggregates, and a larger LWA replacement ratio improved fresh concrete flowability while decreasing SCLC compressive strength.

Using high amounts of fine materials (Portland cement and fine materials) and viscosity-modified admixtures has been determined by researchers to provide high fluidity to SCC as well as overcome segregation and bleeding problems during transporting and placing [20, 21]. To achieve self-compatibility in concrete, it is critical to achieve powder content in the concrete between 500 and 600 kg/m^3 [22]. In addition to being uneconomical, the excessive use of cement is also environmentally unfriendly. Therefore, fly ash, silica fume, and ground granulated blast furnace slag are effective replacement powders. The use of such materials reduces the cost of SCC as well as improves their performance [23]. Significant research has been published on the usage of mineral admixtures like (SF) and (FA) to overcome such challenges and enhance self-compacting concrete suitability [24,25]. Fly ash is produced by the combustion of pulverized coal in a power plant, class F fly ash is characterized by greater pozzolanic qualities and minimal or no cementitious properties. Although SF is produced by the smelting of silicon and ferrosilicon [26].

This investigation aims at highlighting the fresh characteristics of SCLC produced from the ALA manufactured through the cold-bonding pelletization process of expired cement-fly ash with binary and ternary systems of Portland cement, fly ash, and silica fume. Natural coarse aggregates of conventional SCC were partially substituted by ALA at 0%, 50%, and 100%. Portland cement (PC) was substituted with FA contents of 20%, and 10% of silica fume by weight. For this reason, 4 SCLC series were designed. 12 SCLC mixtures were used with a total binder content of 450 kg/m3 and at a constant w/b ratio of 0.38. The workability properties of SCLC mixtures were investigated in the slump flow diameter test, T50 slump flow time test, V-funnel flow time test, L-box height ratio test, and column segregation test. The workability test results were also evaluated.

2. Materials

2.1 Portland Cement, Expired Cement, Fly Ash, and Silica Fume

For the experimental investigation, Al-mass cement I 42.5 R, Portland Cement (PC) was employed to produce (SCLC) and The expired cement (EC) as shown in Figure (1-a), that was used in the manufacture of aggregates was in the concrete laboratory and the expiration date is more than 3-6 months. A portion from EC was agglomerated that needed to be crushed for use, while the remainder was a powder that could be directly used, as illustrated in figure (1-a). The British Chemical Company (dcp) [27] supplied the used fly ash (FA) and it was class F according to ASTM C 618 [26], which was utilized as a secondary binder at a replacement level of 20% by weight of cement and in the production of ALA, as show in figure (1-b). As a mineral additive, silica fume with a surface fineness of 21080 m^2/kg and a specific gravity of 2.25 was added to the mixes. Table 1 lists the chemical compositions and physical attributes of PC, expired cement, SF, and FA.

Table 1: Portland expired cement, silica fume, and fly ash chemical and physical characteristics

Chemical Composition (%)	Portland cement	Expired cement	FA	SF
CaO	45.738	20.00	5.11	0.666
SiO_2	17.584	60.51	47.67	88.59
$Al2O_3$	3.198	4.44	27.73	---
$Fe2O_3$	1.911	5.26	18.42	5.564
SO_3	2.92	2.45	0.34	0.08
MgO	1.531	2.65	2.65	---
Na_2O	0.357	0.344	--	----
K2O	0.841	0.976	--	4.777
Loss on ignition	2.98	2.18	3.71	
Specific gravity	3.15	3.15	2.2	2.25

(a) (b)

Figure 1: (a) Picture of caked EC, and EC powder (b) Picture of fly ash

2.2 Aggregates

2.2.1 Natural aggregates (NA).

Table 2 shows the physical and sieving analysis of natural coarse aggregate from the Al-Nabai region used to make self-consolidating concretes (SCC) with a specific gravity of 2.62 g/cm^3 and a maximum size of (12.5) mm. Natural fine aggregate with a maximum size of 4.75 mm and specific gravity in table 4 was 2.65 from (Al-Ukhaider) complies with Iraqi specification No. 45/1984.[28] Zone 2 was used. Tables (3) and (4) show the physical and chemical properties and grading of natural sand.

Table 2: Sieve analysis and physical properties of natural coarse aggregate

Sieve (mm)	Cumulative passing %	Limits of IQS No.45/1984[28]
20	100	--
14	100	100
10	91	85-100
5	10	0-25
2.36	0	0-5
Specific gravity	2.6	
Absorption %	0.51	

Table 3: Grading of fine aggregate

Sieve Size (mm)	Passing by weight %	Limitation of the specification No.45/1984[28] Zone (2)
4.75	100	90-100
2.36	88	75-100
1.18	70.2	55-90
0.60	59	35-59
0.30	24.4	8-30
0.15	3.2	0- 10

Table 4: Fine aggregate properties: physical and chemical

Physical properties	Test result	Test result Limit of Iraqi specification No.45/1984[28]
Specific gravity	2.62	
Sulfate content %	0.18	specification requirements ≤ 0.5% (max)
Absorption %	3.75	
Bulk density Kg/m3	1665	

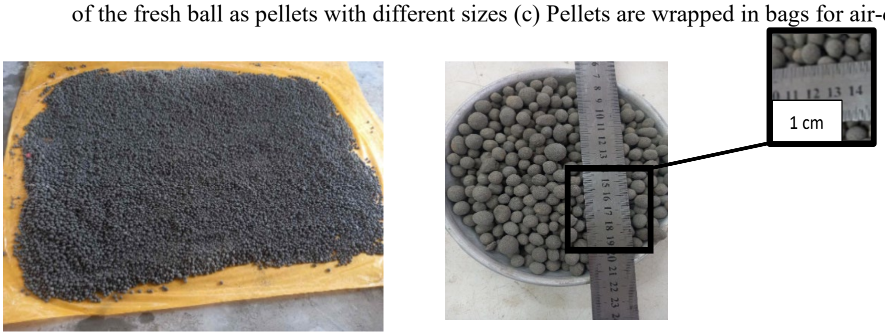
2.2.2 Production of artificial cold bonding coarse lightweight aggregates (ALA)

The first stage of the experimental program was the production of cold-bonding pelletized expired cement (EC) fly ash (FA) artificial lightweight aggregates (ALA) used as coarse aggregates manufactured in an ambient temperature with cemairin (F300) [29] used as the foaming agent in a liquid state with a density of 1.095 kg/l@ 20 °C by (dcp) British building chemical company to produce lightweight foamed aggregates used in the ratio 1:25 one part of water to 25 parts of water [30,31] to reduce the density of aggregates. Trials have been carried out to optimize the rotational speed and inclination angle. With different operation angles and revolution speeds, the effect of changing the inclination angle and rotation speed was tested. 20% (EC) and 80% (FA) by weight in dry state mixing at rotational speed from 20 to 45 rpm with operation angles 45° for 2 minutes. (EC–FA) powder combinations were sprayed with 22% water for 15 minutes before pelletization to coagulate. Pelletization was extended by 10 minutes. The pelletizer disk angle, rotating speed, pelletization period, and moisture content affect EC-FA lightweight aggregate production and characteristics this is agree with the finding in [35]. Figure (2-a) illustrates the disk for pelletization equipped with nozzles for water sprinkling at 45 degrees for aggregate production. The formation of the fresh ball as pellets with different sizes show in Figure (2-b).This stiffens pellets in a curing room at 20°C and relative humidity of 70% for 28 days; the pellets were placed in plastic sealed bags for hardening as indicated in Figure (2-c). At the end of the curing period, the aggregates were sieved according to ASTM C 330 [32] as indicated in Table 5. At saturated surface dry (SSD) conditions as shown in Figure(3-a), the aggregates had a loose bulk density of 865.13 g/m^3 based on the ASTM C 29[33]. It absorbed 12.7% of water by weight in 24 hours measurements are made and a specific gravity of 1.62 according to ASTM C127[34].The final spherical shape of pellets aggregate show in Figure (3-b).

Natural coarse aggregate was used together as a partial replacement with lightweight coarse aggregates to produce SCLC that were agreed with IQS No.45/1984[28] at the same grading of ALA. Specific gravities and Sieve analysis of natural aggregates are presented in Table 2.

(a) (b) (c)

Figure 2: (a) Disk for pelletization equipped with nozzles for water sprinkling at 45 degrees (b) Formation of the fresh ball as pellets with different sizes (c) Pellets are wrapped in bags for air-dry drying



(a) (b)

Figure 3: A photograph of sieved cold-bonded artificial fly ash aggregate and saturated surface dry for ALA

Table 5: Sieve analysis of coarse ALA

Sieve (mm)	Cumulative passing %	Cumulative passing % ASTM C330-04[36]
19	100	100
12.5	96	90-100
9.5	56	40-80
4.75	12	0-20
2.36	0	0-10

2.3 Superplasticizer (SP)

A high-range water-reducing admixture (HRWRA) with the trade name "Sika ViscoCrete® -5930"[37] was employed in this study as a superplasticizer. Table 6 summarizes the superplasticizer characteristics.

Table 6: Technical description of HRWRA

Typical properties	Technical description
Appearance	Turbid liquid
Density	1.095 kg/l.
Chloride content	Nill

3. Mix Proportions Selection and Casting Procedure

As part of the second phase of the experimental program, 12 self-compacting concrete (SCLC) mixes were planned and produced with (w/b) of 0.38 and a total binder content of 450 kg/m3 separated into four series. The first series involves only replacing natural coarse aggregate with 0, 50, and 100% with lightweight aggregate. The second series was created by combining binary mixtures of 20% fly ash and 80% Portland cement. The third series was created by substituting 10% of the cement with silica fume for fixation, again utilizing binary mixes, which was the replacement ratio for coarse aggregates in the first series. The final series was formed through ternary blends of fly ash and silica fume with the same percentages. The later mixes were similar in that natural aggregate was replaced with ALA for both coarse fractions and mineral admixtures in various amounts, as seen in Table 7. Because of the low w/c ratio, mixing fresh mixes can result in bleeding, so additional water must be added to ensure workability. Because lightweight aggregates absorb a lot of water, they were pre-soaked in water for 30 minutes to achieve a saturated dry surface, as shown in Figure 3.

In the first minute of the concrete casting phase, surface-dry, saturated (ALA) were mixed with the binder, and in the second minute, natural aggregates (NA) and (ALA) were added to the mixer. After 30 seconds of homogenization of the particles and binder, two parts of the mixed water containing (HRWRA) were added to avoid segregation. The concrete was then mixed for 3 minutes and allowed to rest for 2 minutes. To finish the mixing process, the concrete was mixed for a total of 2 minutes. To provide EFNARC limitation, (SCLC) slump flow diameters were intended to be in the range of 720±20 mm [16]. Trial batches of each mixture were created using HRWRA in varying amounts until the desired slump flow diameter was obtained to attain this objective workability is required.

Table 7: Mixture proportions of SCLC with fly ash and silica fume for kg/m^3

Series	Mix design	Cement	Fly ash	Silica Fume	SP	water	sand	Natural coarse aggregate	ALA	Fresh Density kg/m^3
Series I	MC0	450	0	0	5.5	171	775	900	0	2302
	MC50	450	0	0	5.5	171	775	450	278	2130
	MC100	450	0	0	5.5	171	775	0	556	1958
Series II	MC0S10	405	0	45	7	171	775	900	0	2290
	MC50S10	405	0	45	7	171	775	450	278	2118
	MC100S10	405	0	45	7	171	775	0	556	1946
Series III	MC0F20	360	90	0	5	171	775	900	0	2276
	MC50F20	360	90	0	5	171	775	450	278	2104
	MC100F20	360	90	0	5	171	775	0	556	1932
Series IV	MC0F20S10	315	90	45	6	171	775	900	0	2264
	MC50F20S10	315	90	45	6	171	775	450	278	2092
	MC100F20S10	315	90	45	6	171	775	0	556	1920

4. Results and Discussion

4.1 Fresh Concrete Properties

The quality of lightweight aggregates (LWA) is often weaker than that of natural aggregate, due to the higher water absorption and lower density of (LWA), problems with workability may arise because the aggregate may move to the surface of the paste viscosity is too low. This problem was solved in this work by adjusting the quantity of (HRWRA) used to control the slump flow of the (SCLC) mixes. Fresh properties of concrete are carried out according to restrictions confined by

EFNARC [16] as shown in Table 8, batches of trials were produced to adjust the amount of superplasticizer for each mixture during this study.

Table 8: Results of fresh properties of self-consolidating concrete

`Series	Mixes	Designation	S.P. L/100 kg powder	Slump Flow (mm)	T500 (Sec.)	V-funnel (Sec.)	T5 min. V-funnel Sec.	L-Box H2/H1	Column Segregation %	Fresh density kg/m3
Series I	M1	MC0	1.1	753	4.2	13.0	18	0.82	7.86	2320
	M2	MC50	1.1	772	3.8	11.0	15	0.88	8.34	2135
	M3	MC100	1.1	785	3.2	9.5	13	0.92	8.56	1947
Series II	M4	MC0F20	1.0	766	4.0	11	14	0.86	7.66	2290
	M5	MC50F20	1.0	778	3.5	9.0	13	0.90	8.23	2102
	M6	MC100F20	1.0	792	3.0	8.0	11	0.94	8.43	1920
Series III	M7	MC0S10	1.3	745	4.6	14.5	16	0.80	7.24	2308
	M8	MC50S10	1.3	768	4.0	12.5	14	0.84	7.13	2122
	M9	MC100S10	1.3	771	3.7	11.0	12	0.88	6.84	1925
Series IV	M10	MC0F20S10	1.2	751	3.9	9.0	13	0.84	6.65	2277
	M11	MC50F20S10	1.2	760	4.1	8.0	12	0.89	6.87	2095
	M12	MC100F20S10	1.2	770	4.4	7.5	10.5	0.92	6.55	1900

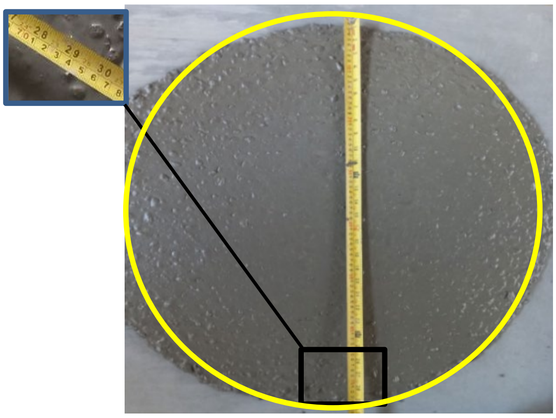
4.2 The Fresh Density of SCLC

In general, the fresh density of lightweight concrete is determined by the mixing ratios, air contents, water demand, particle relative density, and the absorbed moisture content of the lightweight aggregate (ALA) [38]. SCLC research found fresh densities from 2320 to 1900 kg/m^3 (Table 8). In series I, increasing the replacement amount of ALA decreased fresh density, depending on their saturated density (specific gravity). The fresh density of SCLC reduced by up to 8% and 16% for the MC50 and MC100 mixes compared to the control mixture (MC0), which was just a natural aggregate these results agree with the finding of Tang and Brouwers [12]. Because of their lower relative specific weight than Portland cement, mineral admixtures in series II and III diminish the fresh density of series I. In series IV, when the replacement was ternary with silica fume and fly ash in addition to ALA replacement, the lowest fresh density at M12 was 1900 kg/m^3, which was 18% lower than the control mix (MC0), as shown in Table 8.

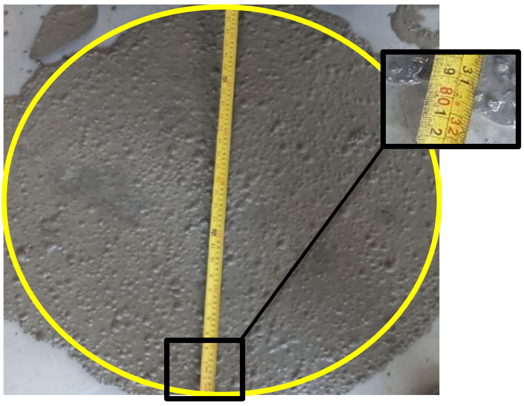
4.3 Slump Flow

Figures (4-a) and (4-b) shown that the aggregate particles had a normal and uniform distribution, preventing all SCLC from bleeding or segregating. In this study made SCLC with slump flow diameters between 750 and 788 mm by adjusting HRWRA amounts as illustrated in Figure (5-a). In series I, the mixture (MC100) containing 100% ALA had the greatest slump flow diameter, whereas the control concrete had the lowest. Moreover, the required HRWRA to obtain the targeted slump flow substantially decreased with increasing the amount of ALA. Figure 4 shows that smooth-surfaced spherical aggregates flow better past one other. The aggregate particles are distributed uniformly without bleeding or segregation. Table 8 shows that the use of ALA from 0 to 100% partially increased the diameter of the slump flow with the same amount of superplasticizer due to ALA are spherical and smooth (series I) In the design of concrete, spherical-shaped aggregates with a smooth surface are preferred because they more readily flow past each other as well as the reduced specific surface area requires less cement and water [5].According to EFNARC [16], the more spherical the aggregate, the less likely the particles are to cause a blockage and the greater the flow is because of reduced internal friction even for MCF100. For instance, (MC100) slump flow increased by 4.7% compared to the control mix. The amount of superplasticizer was reduced in the binary system at series II due to the viscosity of fly ash adjusting properties, which improved the workability when the ALA was changed with the addition of fly ash at 20% as a partial replacement for the cement amount. In contrast, Series III with 10% silica fume replacement required more superplasticizers to achieve the slump flow with the EFRNC[16] restriction because the amount of mixing water was reduced. Finally, as shown in Table 8, series IV needed less superplasticizer than series III, due to the fly ash content which increased the flowability of SCLC.

Figure (5-b) illustrates SCLC slump-flow time to 500 mm. These values show how SCLC don't segregate [20]. SCLC with 50% ALA reaches 500 mm somewhat faster than SCLC with 100% ALA. A 500-mm reference mixture sample slumps in 4.2 s. (MC0). Slump-flow time (T_{500} mm) was 3.8 s for MC50 and 3.2 s for MC100. The T_{500} mm slump flow reduced to 4, 3, and 3.5 s when employing a binary blend of fly ash because the FA spherical particle shape created a "ball bearing" effect that enabled coarser particles to flow more easily and lowered the surface area that needed to be wetted for workability Lo et al. [24] obtained the same ALA findings ternary mixed increased T_{500} mm time.

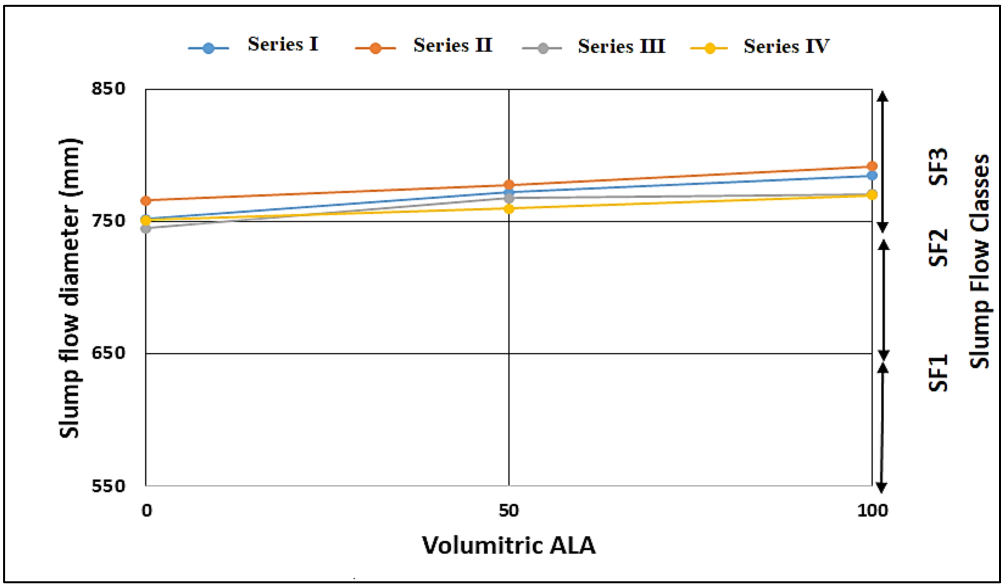


(a) MC0

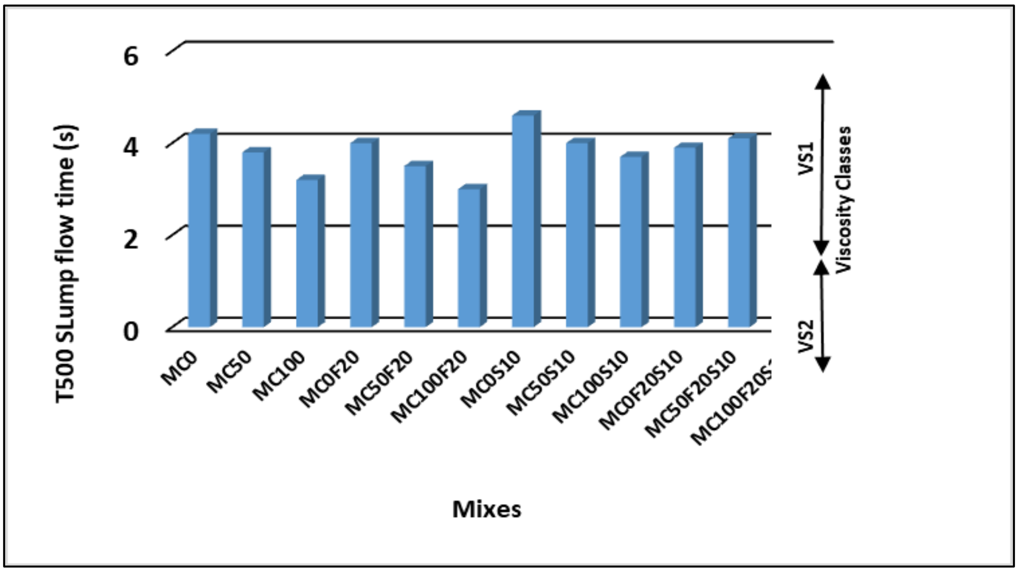


(b) MC100

Figure 4: Typical SCC slump flow.(a) Control combination (100%) natural aggregates, (b) MC100 mixture (100%) ALA



(A)



(B)

Figure 5: (A) the relation slump flow test with volumetric ALA, (B) T500 slump flow time (s) with all mixes

4.4 V-Funnel

As shown in Figure 6, the V-funnel flow time was 7.50–14.5s and was mostly based on ALA and mineral admixtures. As mentioned, raising ALA rates decreases V-funnel time proportionally. MC50 and MC100 mixes had 15.4% and 27% lower V-funnel times than MC0. As fly ash expired cement aggregates replace heavy coarse aggregates, ALA' spherical form aids flow. The flow time is affected by concrete density, which drives its motion. Hence, fresh density decreases V-funnel flow time [15]. As can be seen from Figure 5 using 20% fly ash or silica fume reduces the time needed for the material to flow through the V-funnel, which is caused by using more fine materials and spherical mineral admixtures. The use of SF with 10% replacement increases V-funnel flow durations in the concretes. Ternary FA-SF blends diminish SF harmful effects.

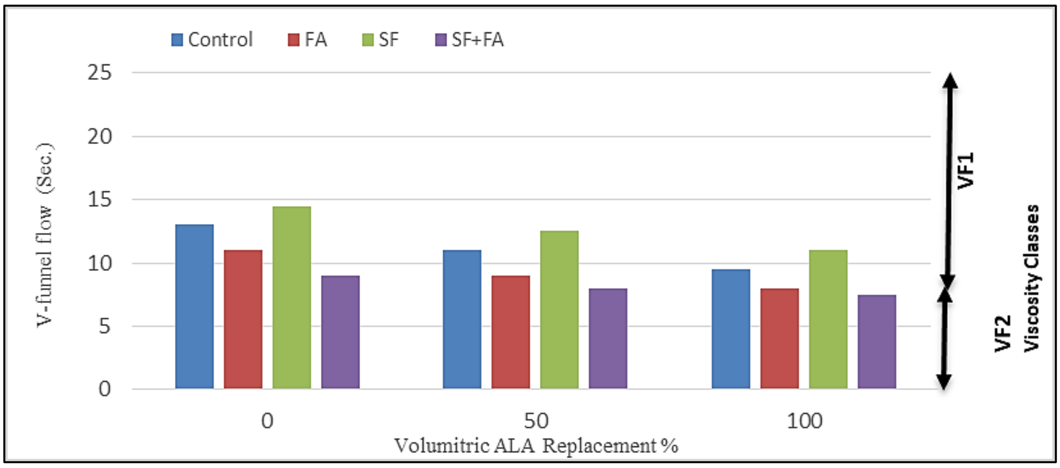
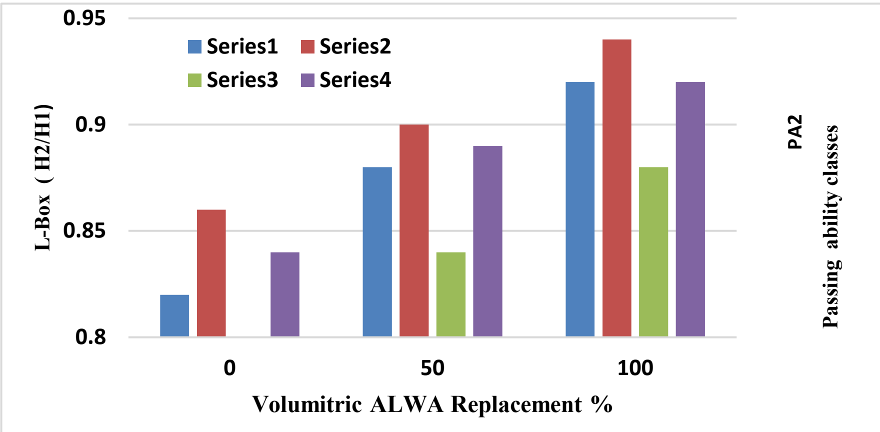


Figure 6: V-funnel flow with volumetric ALA %

4.5 L-Box

Figure (7-a) shows that for all ALA proportions, the H2/H1 ratio satisfied the EFNARC [16] limitation. The reference mixture has the lowest H2/H1 ratio, 0.82, as is evident in Figure (7-a). The L-box height ratio for SCLC increased consistently after the incorporation of ALA, the H2/H1 ratios increase by 7.3% and 12.1%, respectively, causing the MC50 and MC100 mixtures to behave almost fluidly. These findings concur with the results of [8]. This means that there is less chance of clogging and more flow of the fresh mixture because there is less internal friction due to the higher fraction of spherical aggregate particles. Figure (7-b) shows the L-box test apparatus utilized in this study. The series IV ternary blend mixes produced greater L-box height ratio values when compared to series III without stopping, that same meaning in [20]. Also, it was seen that SCLC made with fly ash flows better around obstacles than mixes made with silica fume. This ability to change shape depends on how the particles are shaped. This is also because fly ash is easy to move around, which agrees with [25].

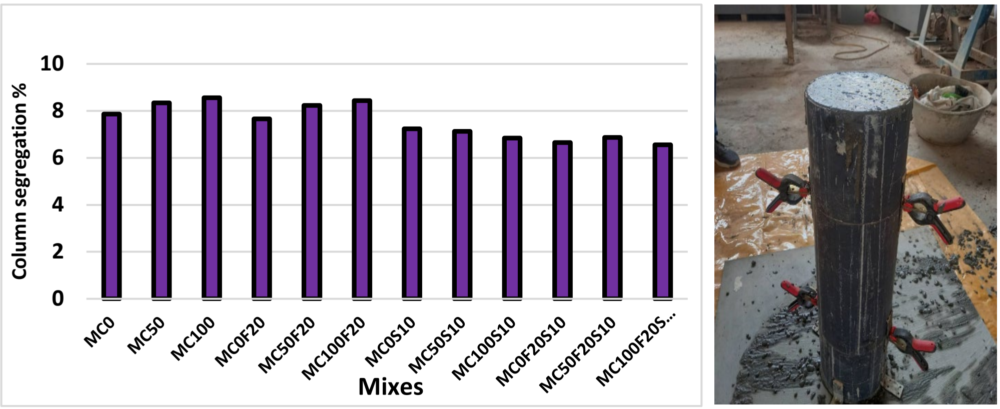


(a) (b)

Figure 7: (a) L-Box results with volumetric ALA replacement % (b) L -box Test Apparatus

4.6 Column Segregation

The reference mix, which only contains natural coarse aggregate (MC0) had a 7.68% column segregation resistance. The column segregation resistance increases from 8.34% to 8.56% when ALA are used as a partial replacement for the volume of natural coarse aggregate at 50% and 100%, respectively, as illustrated in Figure (8-a). This happens because ALA are less dense than naturally occurring coarse aggregate. Silica fume can be used in SCLC to improve column segregation resistance because it increased mortar packing and decreased bleeding which is compatible with [39]. For SCLC mixes containing ALA with fly ash and silica fume, the results of column segregation resistance tests ranged from 6.55% to 6.65%, which were lower than all other mixes because they were more homogeneous and had less bleeding. The apparatus of the column segregation resistance that used in this test is show in figure (8-b).



(a) (b)

Figure 8: (a) Results of column segregation test for all mixes, (b) column segregation apparatus

5. Conclusion

1) The fresh properties of SCLC increased when the EC-FA lightweight aggregates were added since they have a spherical shape and a relatively smooth surface, making them easier to work with in homogeneous, non-segregating concretes, fresh densities ranging from 2320 to 1900 kg/m^3 were attained.
2) All of the SCLC mixtures were designed to have a slump flow diameter that ranged from 753 to 792 mm, variable the amount of superplasticizer used made this possible. There was a greater demand for superplasticizer when SF was employed in binary blends. To maintain the desired slump flow, nevertheless, a bit less superplasticizer was required when FA was used.
3) Slump flow times for all SCLC ranged from 3 to 4.6 seconds. The addition of SF lengthened the period required to reach a 500mm slump diameter. The combinations created in this study were all classed as SF2.
4) The fresh characteristics of SCLC were improved by combining it with fly ash. All of the fly ash SCLC had a faster slump flow time than the control mixture, which only contained Portland cement.
5) A similar trend was also observed in the V-funnel flow times of SCLC. When SF is employed as a 10% replacement, the V-funnel flow times of the SCLC produced are noticeably longer, but the V-funnel flow times of all other combinations, incorporating binary and ternary SF and FA mixtures are shorter. When ternary FA and SF mixes are used together, the negative effects of SF are reduced. The increased ALA percent reduced the V-funnel times.
6) The L-box height ratio is enhanced in all the ternary blend combinations of SF and FA, which leads to a higher filling and passing capacity for SCLC. All of the mixtures had a blocking ratio between 8-1.0. So classification as PA2 in terms of passing ability class.
7) The column segregation results of all SCLC mixes were within the standard limitations, and indicating that ALA, silica fume, and fly ash together, increased the segregation resistance of SCLC.

Author contribution

Conceptualization, Haider Araby Ibrahim and Waleed A. Abbas; methodology, Haider Araby Ibrahim; validation, Waleed A. Abba and Haider Araby Ibrahim; investigation, Haider Araby Ibrahim; resources, Haider Araby ibrahim; writing—original draft preparation, Haider Araby Ibrahim; writing—review and editing, Waleed A. Abbas; visualization, Waleed A. Abba; supervision, Waleed A. Abbas. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

References

[1] E. Benhelal, G. Zahedi, E. Shamsaei, and A. Bahadori, Global strategies and potentials to curb CO_2 emissions in cement industry, J. Clean. Prod., 51 (2013) 142–161. https://doi.org/10.1016/j.jclepro.2012.10.049

[2] J. X. Peng, L. Huang, Y. B. Zhao, P. Chen, L. Zeng, and W. zheng, Modeling of Carbon Dioxide Measurement on Cement Plants, Pro. Environ. Sci. Eng., 610 (2013) 2120–2128. https://doi.org/10.4028/www.scientific.net/AMR.610-613.2120

[3] C. Economy, A. Meddah, C. M. Aziz, and M. Deghfel, The Efficiency of Recycling Expired Cement Waste in Cement Manufacturing : a Sustainable Construction Material, 2022.

[4] M. Aslam, P. Shafigh, M. Z. Jumaat, and M. Lachemi, 'Benefits of using blended waste coarse lightweight aggregates in structural lightweight aggregate concrete, J. Clean. Prod., 119 (2016) 108–117. https://doi.org/10.1016/j.jclepro.2016.01.071

[5] A. M. Nor et al., A review on the manufacturing of lightweight aggregates using industrial by-product, in MATEC Web Conf., 78 (2016) 1067. https://doi.org/10.1051/matecconf/20167801067

[6] S. A. Abera and N. Kumar,A Review on the Production of Lightweight Aggregates Using Industrial Bi-Product and Wastes from Different Sources, 6 (2017) 4-7. https://doi.org/10.21275/ART20178523

[7] P. Perumal, M. Ganesh, and A. S. Santhi, Experimental study on Cold Bonded Fly Ash Aggregates, Int. J. Comput. Civ. Struct. Eng., 2 (2011) 507–515.

[8] M. V. S. Reddy, M. C. Nataraja, and K. Sindhu, Performance of Light Weight Concrete using Fly Ash Pellets as Coarse Aggregate Replacement, Int. J. Eng. Res. Technol., 9 (2016) 95–104.

[9] N. U. Kockal and T. Ozturan, Strength and elastic properties of structural lightweight concretes, Mater. Des., 32 (2011) 2396–2403. https://doi.org/10.1016/j.matdes.2010.12.053

[10] P. Vijay, Use of fly ash aggregates in concrete and its applications in structures, Int. J. Re. Devel. Eng. Technol, 4 (2015) 37-46.

[11] Z. Wu, Y. Zhang, J. Zheng, and Y. Ding, An experimental study on the workability of self-compacting lightweight concrete, Constr. Build. Mater., 23 (2009) 2087–2092. https://doi.org/10.1016/j.conbuildmat.2008.08.023.

[12] P. Tang and H. J. H. Brouwers, The durability and environmental properties of self-compacting concrete incorporating cold bonded lightweight aggregates produced from combined industrial solid wastes, Constr. Build. Mater., 167 (2018) 271–285. https://doi.org/10.1016/j.conbuildmat.2018.02.035

[13] F. Tajra, M. Abd, S. Chung, and D. Stephan, Performance assessment of core-shell structured lightweight aggregate produced by cold bonding pelletization process, Constr. Build. Mater., 179 (2018) 220–231. https://doi.org/10.1016/j.conbuildmat.2018.05.237

[14] E. Güneyisi, M. Gesoglu, O. A. Azez, and H. Ö. Öz, Effect of nano silica on the workability of self-compacting concretes having untreated and surface treated lightweight aggregates, Constr. Build. Mater., 115 (2016) 371–380. https://doi.org/10.1016/j.conbuildmat.2016.04.055

[15] E. Güneyisi, M. Gesoglu, O. A. Azez, and H. Ö. Öz, Physico-mechanical properties of self-compacting concrete containing treated cold-bonded fly ash lightweight aggregates and SiO_2 nano-particles, Constr. Build. Mater., 101 (2015) 1142–1153. https://doi.org/10.1016/j.conbuildmat.2015.10.117

[16] EPG, ERMCO The European Guidelines for Self-Compacting Concrete, Eur. Guidel. Self Compact. Concr., (May), 2005.

[17] M. Gesoğlu, E. Güneyisi, S. F. Mahmood, H. Ö. Öz, and K. Mermerdaş, Recycling ground granulated blast furnace slag as cold bonded artificial aggregate partially used in self-compacting concrete, J. Hazard. Mater., 235–236 (2012) 352–358. https://doi.org/10.1016/j.jhazmat.2012.08.013

[18] M. Gesoğlu, E. Güneyisi, T. Özturan, H. Ö. Öz, and D. S. Asaad, Self-consolidating characteristics of concrete composites including rounded fine and coarse fly ash lightweight aggregates, Compos. Part B Eng., 60 (2014) 757–763. https://doi.org/10.1016/j.compositesb.2014.01.008

[19] I. B. Topçu and T. Uygunoğlu, Properties of autoclaved lightweight aggregate concrete, Build. Environ., 42 (2007) 4108–4116. https://doi.org/10.1016/j.buildenv.2006.11.024

[20] I. S. Agwa, O. M. Omar, B. A. Tayeh, and B. A. Abdelsalam, Effects of using rice straw and cotton stalk ashes on the properties of lightweight self-compacting concrete, Constr. Build. Mater., 235 (2020) 117541. https://doi.org/10.1016/j.conbuildmat.2019.117541

[21] A. M. Falmata, A. Sulaiman, R. N. Mohamed, and A. U. Shettima, Mechanical properties of self-compacting high-performance concrete with fly ash and silica fume", SN Appl. Sci., 2 (2020). https://doi.org/10.1007/s42452-019-1746-z

[22] H. Salehi and M. Mazloom, Opposite effects of ground granulated blast-furnace slag and silica fume on the fracture behavior of self-compacting lightweight concrete, Constr. Build. Mater., 222 (2019) 622–632. https://doi.org/10.1016/j.conbuildmat.2019.06.183

[23] E. Güneyisi, M. Gesoğlu, and E. Booya, Fresh properties of self-compacting cold bonded fly ash lightweight aggregate concrete with different mineral admixtures, Mater. Struct. Constr., 45 (2012) 1849–1859. https://doi.org/10.1617/s11527-012-9874-6

[24] T. Y. Lo, P. W. C. Tang, H. Z. Cui, and A. Nadeem, Comparison of workability and mechanical properties of self-compacting lightweight concrete and normal self-compacting concrete, Mater. Res. Innov., 11 (2007) 45-50. https://doi.org/10.1179/143307507X196239

[25] A. Terzić, L. Pezo, V. Mitić, and Z. Radojević, Artificial fly ash based aggregates properties influence on lightweight concrete performances, Ceram. Int., 41 (2015) 2714–2726. https://doi.org/10.1016/j.ceramint.2014.10.086

[26] Astm, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use, Annu. B. ASTM Stand., (C), (2010) 3–6. https://doi.org/10.1520/C0618-08

[27] Https://www.dcp-int.com/iq/ar, dcp.

[28] 1984 for Aggregates of Natural Resources used for Concrete and Construction. Iraqi Specifications No. (45), Aggregates test.

[29] T. Properties, D. Pale, O. D. Overdosing, C. Cemairin, and S. Cemairin, Cemairin F300 Cemairin F300.

[30] C. L. Hwang and V. A. Tran, A study of the properties of foamed lightweight aggregate for self-consolidating concrete, Constr. Build. Mater., 87 (2015) 78–85. https://doi.org/10.1016/j.conbuildmat.2015.03.108

[31] N. Mohamad Ibrahim, K. N. Ismail, R. Che Amat, and M. Iqbal Mohamad Ghazali, Properties of cold-bonded lightweight artificial aggregate containing bottom ash with different curing regime, E3S Web Conf., 34 (2018) https://doi.org/10.1051/e3sconf/20183401038

[32] ASTM C330, Standard Specification for Lightweight Aggregates for Structural Concrete, ASTM Int., 552 (18), p. 4, 2009.

[33] ASTM:C29/C29M-09, Standard Test Method for Bulk Density (“ Unit Weight ”) and Voids in Aggregate, ASTM Int., i (c), pp. 1–5, 2009.

[34] ASTM C127, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate, Annu. B. ASTM Stand., pp. 1–5, 2004.

[35] A. Frankovič, V. B. Bosiljkov, and V. Ducman, Lightweight aggregates made from fly ash using the cold-bond process and their use in lightweight concrete, Mater. Tehnol., 51 (2017) 267–274. https://doi.org/10.17222/mit.2015.337

[36] C. C. Test et al., Standard Specification for Lightweight Aggregates for Structural Concrete 1, pp. 1–4, 2011,

[37] H. Performance and S. Concrete, Sika ViscoCrete ® -3425, (12), pp. 4–5, 2015.

[38] S. C. C. Bate, Guide for structural lightweight aggregate concrete: report of ACI committee 213, Int. J. Cem. Compos. Light. Concr., 1 (1979) 5–6.https://doi.org/10.1016/0262-5075(79)90004-6

[39] K. Mermerdaş, S. İpek, Z. Algın, Ş. Ekmen, İ. Güneş, Combined effects of microsilica, steel fibre and artificial lightweight aggregate on the shrinkage and mechanical performance of high strength cementitious composite, Constr. Build. Mater., 262 (2020) 120048. https://doi.org/10.1016/j.conbuildmat.2020.120048