*Salud, Ciencia y Tecnología - Serie de Conferencias*. 2025; 4:1546
doi: 10.56294/sctconf20251546

ORIGINAL

# Assessment the Properties of Lightweight Self-Compacting Concrete Incorporating Pozzolanic and Waste Materials as Binary and Ternary Blended Binders

## Evaluación de las propiedades del hormigón ligero autocompactante que incorpora materiales puzolánicos y de desecho como ligantes de mezcla binaria y ternaria

Shimoos Hussain Alsaady[1], Haider M. Owaid[1]

[1]Environmental Engineering Department, College of Engineering, University of Babylon. Babylon 51001, Iraq.

**Cite as**: Hussain Alsaady S, M. Owaid H. Assessment the Properties of Lightweight Self-Compacting Concrete Incorporating Pozzolanic and Waste Materials as Binary and Ternary Blended Binders. Salud, Ciencia y Tecnología - Serie de Conferencias. 2025; 4:1546. https://doi.org/10.56294/sctconf20251546

**Submitted:** 26-08-2024 **Revised:** 01-01-2025 **Accepted:** 25-02-2025 **Published:** 26-02-2025

**Editor:** Prof. Dr. William Castillo-González

**ABSTRACT**

The work investigate methodology of creating lightweight self-compacting concrete (LWSCC), with a specific emphasis on utilizing natural and industrial waste materials and theirs effect on the workability and strength properties. The cement replaced with 10 %, 20 %, and 30 % of (limestone powder (LP)), 10 %, 20 %, and 30 % of (calcined kaolin clay (CKC)), and 20 % (ground granular blast slag (GGBS)) as substitutes of Portland cement in a binary and ternary mixes. Substitution of 30 % CKC decrease slump flow (mm) by 7,5 % compared to control mix while the binary mixes of 30 % LP and 20 % GGBS increased slump flow value by 4,2 % and 3,6 % respectively compared with control mix. Binary mixes decreased in density at all ages, except the mix of 20 % GGBS increase the density by 38 g at 7 days and by 40g at 28 days compared to control mix. Lowest density was observed in binary mixes with 30 % CKC and 30 % LP by 61g, and 51g respectively compared to control mix. The binary mixtures exhibited an increase in compressive strength over time, with the 20 % GGBS mixture demonstrating the most substantial improvements. The 10 % CKC mixture demonstrated notable strength improvements, particularly at 7-day. The 20 % LP mixture demonstrated robust performance, attaining 50,3MPa after 90 days. The 30 % CKC mixture exhibited diminished performance, particularly at initial curing ages. The 10 % LP and 30 % CKC mixtures did not attain strengths equivalent to those of higher LP and lower CKC blends. The control mixture surpassed all combinations.

**Keywords:** Calcined Kaolin Clay; Limestone Powder; Ground Granular Blast Slag; Self-Compacting Concrete; and Waste Materials.

**RESUMEN**

El trabajo investiga la metodología de creación de hormigón ligero autocompactante (LWSCC), con un énfasis específico en la utilización de materiales de desecho naturales e industriales y su efecto sobre las propiedades de trabajabilidad y resistencia. El cemento se sustituyó con un 10 %, 20 % y 30 % de (polvo de piedra caliza (LP)), 10 %, 20 % y 30 % de (arcilla de caolín calcinada (CKC)), y 20 % (escoria granulada molida (GGBS)) como sustitutos del cemento Portland en mezclas binarias y ternarias. La sustitución del 30 % de CKC disminuyó el flujo de asentamiento (mm) en un 7,5 % en comparación con la mezcla de control, mientras que las mezclas binarias de 30 % de LP y 20 % de GGBS aumentaron el valor del flujo de asentamiento en un 4,2 % y un 3,6 % respectivamente en comparación con la mezcla de control. Las mezclas binarias disminuyeron la densidad en todas las edades, excepto la mezcla de 20 % GGBS que aumentó la densidad en 38 g a los 7 días y en 40 g a los 28 días en comparación con la mezcla de control. La densidad más baja se observó en las mezclas binarias con un 30 % de CKC y un 30 % de LP en 61 g y 51 g respectivamente en comparación con la mezcla de control. Las mezclas binarias mostraron un aumento de la resistencia a la compresión con el tiempo, siendo la mezcla con 20 % de GGBS la que mostró las mejoras más sustanciales. La mezcla con un 10 % de CKC mostró notables mejoras en la resistencia, especialmente a los 7 días. La mezcla de 20 % LP demostró un rendimiento robusto, alcanzando 50,3MPa después de 90 días. La mezcla con un 30 % de CKC mostró un menor rendimiento, especialmente a las edades iniciales de curado. Las mezclas con un 10 % de LP y un 30 % de CKC no alcanzaron resistencias equivalentes a las de las mezclas con mayor LP y menor CKC. La mezcla de control superó a todas las combinaciones.

**Palabras clave:** Arcilla Caolínica Calcinada; Caliza en Polvo; Escoria Granular Molida; Hormigón Autocompactante y Residuos.

## INTRODUCTION

Self consolidation concrete has attracted significant interest from academics, and industry because of the distinctive capacity to fill full shapes, flow, and compacting concrete. (SCC) has mechanical and durability performance that is either equal to or superior to traditional vibrated concrete (VC). Application of self-compacting concrete (SCC) has significantly rised over years, especially in the precast concrete industry.[1,2,3]

LWSCC a unique building material that combines advantages of lightweight with self compacting concrete. LWSCC has the ability to self-dispersal and tack the designated location within the formwork, enclosing reinforcement mitigating problems such as segregation and bleeding. Its principal applications lies in reinforcement-intensive structural components and elements designed for seismic resilience, due to its self flowing and lightweight characteristics. The material is especially advantageous in construction where strong compressive strength for concrete is not required, but lower weight is essential.[4] This type of concrete has emerged as a vital element in the construction industry's innovation efforts due to its significant benefits for the environment, health, safety, and comfort of concrete workers. Since its establishment thirty years prior. Lightweight expanded clay aggregate (LECA) widely utilized in numerous research study.[5,6,7,8] An experimental study by[5] sought to partially substitute the coarse aggregate in M25 grade concrete, utilizing a mix design based on IS 10262:1982, with LECA, In the preparation of five different combinations, with replacement percentages varying from 20 % to 100 %, both density and strength exhibited a linear decline as the replacement percentage increased. Compressive strength of the concrete decreased to below (25 N/mm$^2$) when 60 % of the coarse aggregate was replaced, whereas concrete with 100 % (LECA) maintained a strength over (17 N/mm$^2$), suggesting that it can use as a lightweight structural material. Supporting these researchs by[6,7,8] further clarified the characteristics of fresh and hardened concrete with a higher proportion of light expanded clay aggregates substituting traditional aggregates. In this study demonstrate the reduction in concrete density and the improvement in workability with increasing replacement percentages, but this was accompanied by a decline in compressive strength, splitting tensile strength, and flexural strength of the concrete.

Durability is an increasingly important element of the construction field, in which building materials are essential to engineering.

The construction industry is recognized as being one of the more polluting sectors due to its significant Carbon emissions.[9] Each metric ton of cement produced generates around 0,9 metric tons of $CO_2$, with an extra 0,1 metric Tons emitted during the production of each metric ton of concrete. The effective mitigation of these repercussions is crucial, and researchers globally have aggressively advocated for the reduction of $CO_2$ emissions through the decrease of cement content in concrete.[10] Common industries such as metal casting, thermal power generation, copper manufacture, vehicle manufacturing, and glass production are responsible for generating slags and by-products that, despite being reused, are ultimately abandoned and deposited in landfills. An acute rise in transportation and disposal expenses, coupled with a scarcity of landfills, mandates the efficient usage of these by-products. Inadequate waste disposal systems result in land degradation, leading to health and many environmental issues. According to[11] lightweight concrete is a mixture of conventional coarse and fine particles, characterized by a density ranging from 1442 to 1842 kg/m3 and a compressive strength above 17 Mpa. It finds application in permeable constructions and is integrated into (SCC) mixtures to decrease their final weight. The ideal ratio of concrete mixtures (SCC) is to decrease their final weight. The ideal ratio is 15 %, and all mixes of (SCC) exhibit exceptional compressive strength and splitting tensile strength.[12] The present study examines performance characteristics of structural lightweight aggregate concrete and its correlation with density class. Three lightweight concrete mixtures were developed with densities of 1000 and 1400 kg/m3 by the use of optimal particle packing theory. The concretes exhibited exceptional structural efficiency, as evidenced by their 28 day compressive strengths of 23, 28, and 42 Mpa. A highly accurate prediction formula was suggested, and the mixtures exhibited exceptional durability characterized by limited water penetration and minimal mass loss.[13] The research on sustainable composite construction (SCC) mix design, supplementary materials, fiber reinforced SCC, recycled aggregate, nanotechnology, and artificial intelligence highlights the benefits of SCC in the construction industry and its sustainability. It suggests incorporating various materials without compromising self compactability and mechanical properties, reducing carbon footprint and cost.

Future research should focus on adding multiple types of agricultural waste, exploring nanomaterial, hybrid and natural fibers, and examining the influence of nanomaterial on SCC workability and durability. The planet will persist in warming over time as humans continue to release any Carbon Dioxide emissions. Accordingly, the use of pozzolanic elements in concrete can significantly reduce CO2 emissions.(14) A study by(15) investigates the effects of nanolime particles (NL) on the properties of self compacting geopolymer concrete reinforced with micro steel fibers based on calcined kaolin clay (CKC). Results show that NL adversely impacts fresh attributes, but at a 2 % concentration, it significantly improves mechanical and durability properties,(16) focus on the use of lightweight aggregates LWA and minerals to create lightweight self-compacting concrete (LWSCC) that is thermally insulating. It was discovered that adding expanded glass aggregate with porous structure raises both the water demand and the water absorption capacity.(17) Another research focus on the microstructure and mechanical characteristics of (LWSCC) with a replacement ratio of rice straw ash (RSA) and cotton stalk ash (CSA) is investigated in this work. The study of(18) investigated the influence of waste expanded polystyrene beads on the toughness and workability characteristics of (LWSCC). The study used a blend of EPS with coarse aggregate, Portland cement, waste ceramic powder, and fine aggregate, and the results showed an improvement in flowability, segregation resistance, and workability with increasing ESP waste replacement levels. The slump flow diameter increased with increasing EPS content, with 80 % of EPS having the greatest SFD of 820 mm. When EPS was used, the compressive strength went down. Overall, the sustainable LWSCC mixtures reached their limit and met structural needs, which made them cleaner and better for the environment.

This study is to investigate the influence of pozzolanic materials and waste products, specifically ground granular blast slag (GGBS), calcined kaolin clay (CKC), and limestone powder (LP), on the strength properties of lightweight self-compacting concrete (LWSCC). We analyzed many mixtures, encompassing binary and ternary mixes. Novel attributes were evaluated, including slump flow diameter, T500, V-funnel, L-Box high ratio, and segregation resistance. We evaluated the compressive strength at 3, 7, 28, 56, and 90 days, and the bulk density at 7 and 28 days. Numerous researches has examined the impact of substituting a portion of cement with pozzolanic and industrial waste materials in lightweight concrete composed of both light and regular aggregates, as well as in self-compacting concrete. This research concentrated on substituting cement with pozzolanic and waste materials in lightweight self-compacting concrete, utilizing light expanded clay aggregate as the coarse aggregate. This study aims to yield essential information that supports the incorporation of cement substitute materials in the construction of high-performance lightweight self-compacting concrete (LWSCC). We expect these disclosures to decrease cement consumption, lower CO2 emissions, and improve the environmental sustainability of LWSCC.

## METHOD
### Materials
*Cement*

The present work employed Karasta type I cement. Utilizing cement that complies with the applicable local standard is crucial to ensure the performance and longevity of the concrete in its designed application use. Table 1 and 2 detail the physical and chemical properties, which were verified to confirmed with the Iraqi Specification.(19)

**Table 1.** Chemical composition and main compounds of Karasta type I cement

| Chemical Composition | Percentage % | Limit of IQS of. 5/2019 |
|---|---|---|
| CaO | 64,78 | --- |
| Fe2O3 | 3,19 | --- |
| Al2O3 | 4,78 | --- |
| SO3 | 2,45 | 2,8 if C3A > 5 % |
| L.O.I. | 1,78 | ≤4 % |
| MgO | 1,76 | ≤5 % |
| L.S.F | 0,94 | (0,66-1,02)% |
| I.R. | 0,21 | ≤ 1,5 % |
| main compounds (Rogue's equation) | | |
| (C3S) | 55,57 | --- |
| (C2S) | 23,01 | --- |
| (C3A) | 7,28 | --- |
| (C4AF) | 9,70 | --- |

**Note:** *The Chemical test was conducted in the laboratories of the Civil Department at Babylon University, College of Engineering.

**Table 2.** Physical properties*

| Physical Properties | Test Result | Limit of IQS No:5/2019 |
|---|---|---|
| surface area $cm^2/g$ (Blaine method) | 3250 | ≥ 2800 |
| Setting time | | |
| initial setting time (min) | 185 | ≥45 |
| Final setting time (min) | 235 | ≤ 600 |
| Compressive Strength | | |
| 2days Mpa | 24 | ≥ 20 |
| 28 days Mpa | 42,6 | ≥ 42,5 |

**Note:** * As reported from the factory

*Limestone powder*

LP is a versatile material obtained by the meticulous crushing and grinding of limestone minerals. It is a finely ground powder appropriate for a broad spectrum of uses. Construction items, such as concrete and mortar, extensively utilize limestone powder in their manufacturing process. Limestone powder is well recognized for its exceptionally high calcium carbonate content and the ability to improve both chemical and physical characterizes of the concrete.

LP used in this research was locally sourced in Iraq, (Al Noura Factory in Karbala), it is known as "Al-Gubra". This is a locally available and relatively inexpensive material. The limestone powder served as a substitute for cement in LWSCC mix. LP was ground by a blowing method to ensure the particle size was smaller than 0,00125cm (0,125 mm), as recommended by[20]. Table 3 and 4 show physical and chemical properties of limestone used in this study according to manufacturing.

**Table 3.** Chemical analysis of limestone powder

| Component% | Test result | Limites* | Conform |
|---|---|---|---|
| CaO+MgO | 93,27 | Min 85 % | OK |
| MgO | 0,16 | Max 5 % | OK |
| Fe2O3 | 0,27 | | |
| Al2O3 | 0,80 | | |
| SiO2 | 2,71 | | |
| Fe2O3+Al2O3+SiO2 | 3,78 | Max 5 % | OK |
| SO3 | 0,29 | | |
| L.O.I | 2,36 | | |
| Total | 99,7 | | |

**Note:** *Limits according to[21]

**Table 4.** Physical properties of limestone powder

| Physical Testes | Result | Limits | Conform |
|---|---|---|---|
| Setting time | 8 | 5-15 min | OK |
| CO2 % | 2,90 | Max 5 % | OK |
| (activity) | 90,28 | | |

*Calcined kaolin clay*

Metakaolin (MK) is commonly referred to as calcined kaolin clay (CKC). Calcined kaolin clay is not the result of an industrial process, but is deliberately produced for special purposes under closely controlled conditions. The production of metakaolin involves subjecting the naturally abundant clay mineral kaolin to temperatures between 650-900℃.This controlled heating process, called calcenation, results in the structural breakdown of the kaolin. The calcenation process eliminates bound hydroxide ions and introduces disorder within the alumina and silica layers, resulting in an exceptionally responsive and non-crystalline material with both pozzolanic and latent hydraulic reactivity. These properties make metakaolin suitable for various cementing applications.[22] Chemical analysis and physical properties of the specific metakaolin in the study is given on table 5 and 6. In this study the specifications of Kaolin used compatible with.[23]

**Table 5.** Chemical composition of calcined kaolin clay and loss of ignition (LOI)

| Chemical composition | value |
|---|---|
| ($SiO_2$) | 53 + 2 |
| (MgO) | 0,151 |
| ($Al_2O_3$) | 45 +2 |
| (CaO) | 0,193 |
| ($K_2O$) | 0,071 |
| ($Na_2O$) | 0,08 |
| ($Fe_2O_3$) | 0,268 |
| ($TiO_2$) | 0,76 |
| (LOI) | 11,73 |

**Table 6**. Physical properties of (CKC)

| Particle size | 325 mesh |
|---|---|
| Moisture | <0,5 |
| PH value | 6,0- 8,0 |

*Ground Granulated Blast Furnace Slag (GGBS)*

GGBS is byproduct of the blast furnaces employed in iron manufacturing. This operates at temperature of around 1500℃ and utilizes a meticulously controlled mixture of iron ore, coke, and limestone. The iron ore is transformed into iron, while the remaining materials from a slag that floats on the iron. The GGBS is separated from the unreacted components and rapidly cooled. This produces glassy granules that are later ground into a fine powder. GGBS functions as a alternative to Portland cement and offers further advantages to concrete mixtures.[24] The Chemical characteristics of GGBS used in this study according to manufacturing as in table 7.

**Table 7**. Chemical properties of GGBS

| Chemical composition | % by weight |
|---|---|
| $SiO_2$ | 34,40 |
| $Al_2O_3$ | 13,26 |
| $Fe_2O_3$ | 0,43 |
| MgO | 8,83 |
| MnO | 0,29 |
| CaO | 38,94 |
| $Na_2O$ | 0,38 |
| $K_2O$ | 0,59 |
| $SO_3$ | 0,29 |
| LOI | 1,17 |
| $TiO_2$ | 0,94 |
| $S^{2-}$ | 0,99 |
| C | 0,09 |
| $Cl^-$ | 0,011 |
| Activity | |
| 7 days activity index | 65 % |
| 28 days activity index | 90 % |

*Fine aggregate*

Numerous parameters effect the creation of (SCC), including quantity, grade, and shape of the fine aggregate. This study employed fine aggregate with a fineness modulus of 3,23. this value aligns with the third gradation zone as per IQS No.45 (1984), this figure corresponds to the third gradation zone. The gravel's specific gravity was measured at 2,65, with an absorption rate of 1 % and a sulfate concentration of 0,34 %, according to IQS No.45.[25]

*Light Expanded Clay Aggregate (LECA)*

LECA exhibited a particle size about 0,475 cm to 1cm, and the source from northern of Tehran, Iran. LECA is defined by its porous ceramic structure, which features uniform, small, closed-cell pores and densely sintered, robust exterior surfaces. LECA produced by incinerating clay minerals in rotary kilns at temperatures ranging from 1100-1200℃, resulting in the particles expanding and greatly increasing in volume. Table 8 delineates the graduation requirements from[26] for lightweight aggregates, accompanied by the test outcomes for LECA utilized in this research. Table 9 and 10 present the physical and chemical properties of lightweight aggregate.

**Table 8.** Graduation requirements from ASTM C330-2017

| Sieve size (mm) | Cumulative passing % | Limits of ASTM C330 |
|---|---|---|
| 12,5 | 100 | 100 |
| 10 | 100 | 80-100 |
| 8 | 79 | - |
| 6 | 46 | - |
| 4,75 | 5 | 5-40 |
| 2,36 | 2 | 0-20 |
| 1,18 | 0 | 0-10 |

**Table 9.** Physical properties

| Physical properties | Test result |
|---|---|
| Specific Gravity | 1,26 |
| Bulk Density(Loose) | 700 |
| Water Absorption | 12 % |

**Table 10.** Chemical composition of LECA

| CaO | SiO2 | Al2O3 | MgO | SO3 | Fe2O3 | L.O.I | TiO2 | MnO2 | Na2O | K2O |
|---|---|---|---|---|---|---|---|---|---|---|
| 3,78 | 61,58 | 16,99 | 2,56 | 2,45 | 7,62 | 0,2 | 0,8 | 0,1 | 1,03 | 2,34 |

**Note:** *The chemical testes from the factory of LECA.

LECA was immersed in water for a minimum of 48 hours prior to utilization, as illustrated in plate 1. This was done to inhibit the LECA from absorbing water during the mixing process, due to its high water absorption capacity.

After the 48- hour immersion, the LECA was spread out in laboratory conditions until the surface became dry. This ensured a saturated surface-dry (SSD) condition. The purpose of these steps is ensure that the LECA does not absorb or release water during the concrete mixing and casting process, which could affect the water-to- cement ratio and the properties of the resulting concrete. Maintaining the LECA in an SSD condition helps to maintain a consistent and predictable behavior of the LECA in the concrete mixtures.

**Figure 1.** LECA immersed in water

https://doi.org/10.56294/sctconf20251546

*Admixture (HRWR)*

High range water reducing (HRWR) Sika® ViscoCrete®-180 GS, slump retaining and super plasticizing, retarding admixture for concrete and mortar meets the requirements of[27] used in this study. Table 11 shows the properties of superplasticizer used in the study.

Many mixtures prepared with different proportions of the superplasticizer, regarding from 0,5 % to 2 %. The superplasticizer was added with one-third of mixing water. After conducting tests on LECA in the wet condition, it was found that a 1 % ratio is the ideal amount to use in lightweight self-compacting concrete, which was adopted in this study.

**Table 11.** Properties of Superplasticizer

| **Form** | **Viscous liquid** |
|---|---|
| Appearance | Light brownish |
| PH | 4 - 6 |
| Storage | Under dry conditions at temperatures between +5°C and +35°C. Protect from direct sunlight. Re-circulation is necessary when stored for extended periods. |
| Composition | Aqueous solution of modified polycarboxylates |
| Specific gravity | 1,070 ± ( 0,02 ) g/cm3 |
| **Note:** *According to manufacturer. | |

*Water*

The water used is tap water, which is defined as regular municipal or city water supply. The tap water is stored in tanks inside the laboratory, which allows any suspended particles, such as clay or dirt, to settle out and precipitate to the bottom of the tanks. The purpose of storing the tap water in the tanks is to remove any sediment or particulates that may be present in the raw tap water, thus ensuring that the water used for mixing and treatment is cleaner and free of suspended solids

**Mix proportion**

There is no standard procedure for designing LWSCC mixtures, so experiment with various proportions of the components to achieve the requisite fresh and hardened properties. From these experimental mixes, the best-performing combinations were selected based on their fresh properties and compressive strength. This study, eleven LWSCC mixtures were produced and evaluated with the help of European standards (EFNARC, 2005) to create the SCC mixtures. The proportions of materials were selected according to previous studies.[28] The raw materials maintained in a water/ratio of 0,35 and a total binder concentration of 543 kg/m$^3$ and Superplasticizer was added to the cement at rate of 0,1 % of its weight. Three concrete samples of dimensions 10×0×10cm were used to assess the compressive strength.

**Table 12.** Mix proportions of LWSCC

| Mixtures | Cement kg/m3 | LP kg/m3 | CKC kg/m3 | Fine aggregate kg/m3 | Coarse aggregate (LECA) kg/m3 | Superplastyciser % | Water Kg/m3 |
|---|---|---|---|---|---|---|---|
| Control Mix (PLC) | 543 | 0 | 0 | 697 | 453 | 1 | 190 |
| 10 % LP | 488,3 | 54,3 | 0 | 697 | 453 | 1 | 190 |
| 20 % LP | 434,4 | 108,6 | 0 | 697 | 453 | 1 | 190 |
| 30 % LP | 380,1 | 162,9 | 0 | 697 | 453 | 1 | 190 |
| 10 % CKC | 488,3 | 0 | 54,3 | 697 | 453 | 1 | 190 |
| 20 % CKC | 488,3 | 0 | 108,6 | 697 | 453 | 1 | 190 |
| 30 % CKC | 434,4 | 0 | 162,9 | 697 | 453 | 1 | 190 |
| 20 % GGBS | 434,4 | 0 | 0 | 697 | 453 | 1 | 190 |
| 10 %LP+ 20 %GGBS | 380,1 | 54,3 | 0 | 697 | 453 | 1 | 190 |
| 10 %CKC+ 20 %GGBS | 380,1 | 0 | 54,3 | 697 | 453 | 1 | 190 |
| 10 %LP+ 10 %CKC | 380,1 | 54,3 | 54,3 | 697 | 453 | 1 | 190 |

Four trial mixes were initially tried to create a reference mix. Cement was then partially replaced with different proportions of limestone powder (LP) and (GGBS). The concrete specimens tested at 3, 7, 28, 56, and 90 days. Three binary mixes were created by replacing cement with 10 %, 20 %, and 30 % of limestone powder, and binary mix with 20 % of GGBS and three binary mixes were cast by replacing cement with 10 %, 20 %, and 30 % of GGBS. And three ternary mixes: 10 % LP with 10 % CKC, 10 % LP with 20 % GGBS, and 10 % CKC with 20 % GGBS.

### *Mixing Procedures, Spacing, Casting, Curing, and Testing*

#### Mixing procedure

Based on prior mixing methodologies in international research,[29] the steps of the mixing procedure were executed as follows:

1. The dry constituents, including cement, (pozzolanic or waste materials), sand, and course aggregate (LECA), mixed until a homogeneous dry mixture was achieved.
2. Subsequently, one-third of mixing water added and blended roughly for one minute.
3. Residual mixing water was then included, along with the complete amount of Superplasticizer.
4. Mix for 3 minutes more.
5. Let the mix 2 min rest before casting in to the molds. As shown in figure 2.

**Figure 2.** The steps of the mixing.

#### Specimens of Concrete

Criterion specimens of concrete were fabricated to examine the characteristics of LWSCC. Subsequently, the specifics of the samples were elucidated.

3 cubes (100×100×100 mm) casted identically for every mix to evaluate compressive strength and bulk density as see in figure 3.

**Figure 3.** Specimens of Concrete

https://doi.org/10.56294/sctconf20251546

**Casting and Curing of Specimens**

The molds and the internal surface were cleaned and lubricated to prevent adhesion following the curing of concrete. The samples were subsequently encased in a polypropylene sheet in the laboratory for approximately 24 hours, after which they were meticulously demolded then immersed in water for duration of 2, 27, 55, and 89 days.

***Testing***

**Fresh properties testes**

*Slump flow diameter (mm)*

Slump test evaluates the deformability of (SCC) without obstacles the methodology specified by EFNARC (2005). This test evaluates filling capacity by monitoring the horizontal flow and assesses mix viscosity by timing the duration for SCC to reach 500 mm flow distance. The simplicity of this test allows for visual detection of segregation resistance.

The slump test may be conducted using either an inverted or upright Abram's cone, applicable in situ or within a laboratory setting. The cone placed on a flat steel surface that is leveled and non-absorbent, with a minimum area of 900mm*900mm it is filled with LWSCC and raised to a height of 15 to 30mm within 2 to 4 seconds; under the force of gravity the LWSCC flows out. The documented measurements pertain to tow diameters, d1 and d2, which are orthogonal and horizontal to one another, as illustrated in figure 4 the mean diameter of flow spread, SF, is subsequently calculated using the equation (1) presented below:

Largest diameter of the flow spread (mm).

Diameter of the flow spread at right angle to D max (mm).

$$\text{Slump flow} = \frac{largest\ diameter\ of\ flow\ spread(D1) + diameter\ of\ flow\ spread\ to\ the\ righre\ angle\ to\ d1\ (D2)}{2} \quad (1)$$

**Figure 4.** Slump flow test

*V-Funnel test*

**Figure 5.** V-funnel test

https://doi.org/10.56294/sctconf20251546

V-funnel test assessed filling capacity and viscosity of (SCC) the test conducted in accordance of EFNARC (2005), utilizing device with the dimensions illustrated in figure 5.

*L-Box test*

The test evaluated the capacity of SCC to pass through narrow gaps, such as gaps in reinforcement net. The procedure was executed according to the methodology specified by EFNARC 2005, utilizing an L-shaped box featuring a gate on the vertical section and three ϕ12 smooth bars, as seen in figure 6. After saturating the box, fresh concrete was added into the vertical section of the L-box and allowed to settle for one minute. Thereafter, the sliding gate was raised, permitting the concrete to flow through the horizontal segment of the L-box. The height of the concrete was measured at two specific points: initially, in the beginning the horizontal section (H1), and then the end of the same segment (H2). H2/H1 calculated and matched them to the EFNARC, 2005 specification.

**Figure 6**. L-Box test

*Segregation Resistance*

Segregation resistance refers to a fresh mix's capacity to preserve its initial sufficiently uniform dispersion of constituent ingredients. This test evaluates segregation resistance of (SCC). The apparatus and methodology according to specified in EFNARC (2005). The segregated portion (SR) was computed using equation (2).

$$(SR)\%= \frac{mass\ of\ receiver\ and\ concrete(g) - mass\ of\ receiver(g)}{mass\ of\ concrete(g)} \times 100 \quad (2)$$

The use of these established testing methods from the EFNARC 2005 guidelines. Provides a robust and standardized approach to comprehensively characterize the essential fresh properties of SCC, covering flow ability, filling capacity, and passing ability.

**Hardened Properties Tests**

*Bulk Density*

Bulk density of concrete is a critical property that has significant effect on the performance and design of structures. The bulk density directly determines the self weight of concrete and overall structure. This is crucial for structural design, as the dead load from the concrete's own weight needs to be accounted for. For LWSCC, the use of lightweight aggregates results in lower bulk density than normal weight concrete. This decrease in weight can be advantageous for particular uses, such as skyscrapers or long-span bridges.

Bulk density, along with other factors like water content and admixtures, influences the workability and flow ability of LWSCC as per the standard referenced.[30] Maintaining the optimal bulk density is crucial for attaining the self compacting properties of LWSCC, hence preventing difficulties like segregation or bleeding, which can compromise the concrete's integrity and durability. The bulk density allows for accurate calculation of the concrete's volume and mass in the mix design process. This ensures the proper proportioning of the constituent materials, such as cement, aggregates, and water. For LWSCC, the lower bulk density compared to normal-weight concrete needs to be accounted to achieve the desired fresh and hardened properties. Measuring bulk density of LWSCC is a standard quality control test that helps ensure the consistency and uniformity of the produced concrete. In this research, the bulk density was calculated in two ages, 7 and 28 days.

The mean outcomes of three cubic specimens measuring (100×100×100) mm were documented.

Density= m/v (3)

Where:
m: the mass of the specimen in air (kg).
v: the volume of specimen determined from its dimensions ($m^3$).

*Compressive strength*

Compressive strength of cubes (100×100×100 mm) of (LWSCC) was assessed using a hydraulic compression machine according to the testing standard BS 1881: Part 116 (1983). The loading rate used was 18 Mpa/min. Average of three cubes were tested at 3, 7, 28, 56, and 90 days to evaluate the hardened properties of the LWSCC. Compressive strength is a fundamental evaluation for understanding the mechanical performance and durability of (SCC). This testing methodology provides important insight into the hardened properties and quality of the LWSCC material over time. The compressive strength results at these key curing ages are crucial data points for assessing the suitability and expected performance of the LWSCC in real-world applications.

## RESULTS AND DISCUSSION

### Fresh properties results and discussions

*Slump flow test results (D, T500)*

The lower slump values were obtained by (10 % CKC, 20 % CKC, and 30 % CKC) for binary blend systems, respectively, of LWSCC. As seen in figure 7, most concrete mixes could be conformed to SF3 class in terms of slump flow according to EFNARC, 2005. Except for the binary mixture containing (10 % CKC), which was located within the SF2 class.

In binary mixes (10 % LP, 20 % LP, 30 % LP, 20 % GGBS) the slump flow diameter increases by (1,25, 2,50, 4,40, 3,77) % respectively, the values of T500 decreased by (7,40, 11,11, 18,51, 18,51) %, and the values of V-funnel decreases by (21,73, 26,08, 31,52, 32,60)% respectively when compared to control mixture as shown in figures 7 and 8. The lowest T500 and V-funnel flow of 2,1s and 6,2 s, respectively, while 30 % CKC mix had the highest T500 by 4,2s and the highest V-funnel value by 11,4 s. Including CKC generally makes the concrete more viscous. This is consistant with what was found in the reserch by[31] and[32].

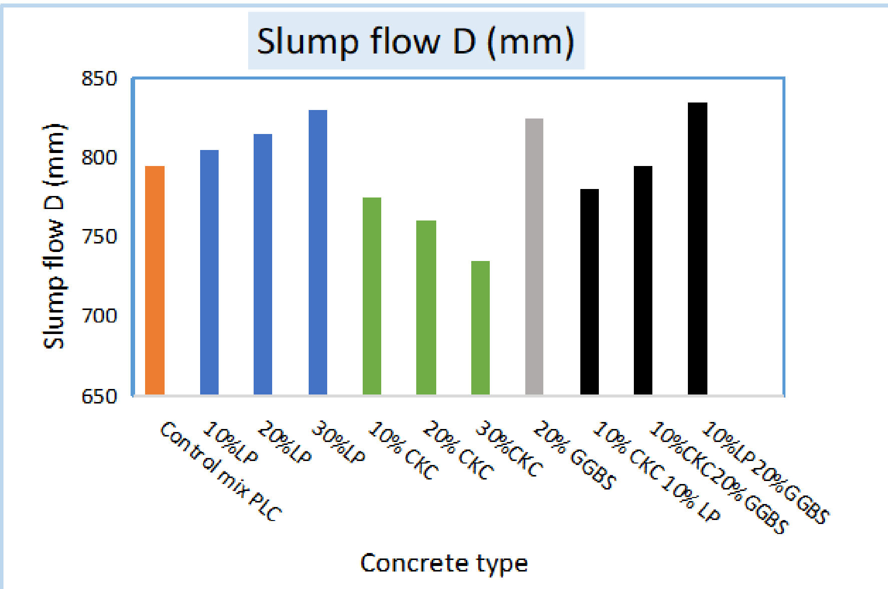


**Figure 7.** Slump flow diameter (mm) for binary and ternary LWSCC mixes

The shape of (CKC) particles, characterized by elongated hexagonal plates that impede the fresh mixture and increase interparticle friction, may account for the observed outcomes. Nonetheless, the uneven or plate-like morphology of the CKC particles is considered to diminish the mixture's capacity for expansion, resulting in decreased slump- flow diameters.

The pozzolanic materials employed (GGBS and LP) exhibit a low water absorption capacity, hence allowing additional water to enhance flowability greatly, resulting in reduced water requirements. Comparable patterns were also reported by other researchers.[31,32,33]

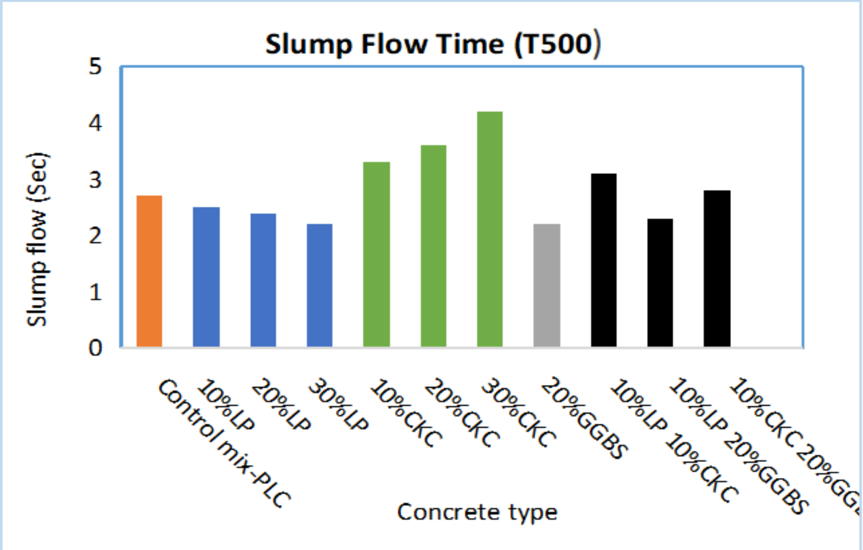


**Figure 8.** Slump flow time (sec) for binary and ternary LWSCC mixes

*V-funnel test*

The values in figure 9, show the V-Funnel for control mix (PLC) is 9,2 (sec). Replacing the 10 % to 30 % of cement by LP decreased V-funnel time from 7,2 (sec) to 6,3 (sec), indicating improved viscosity and flow properties.

Mixture with 10 % CKC shows a V-funnel time of 9,4 sec, which means replacing cement with 10 % CKC leads to a decrease in flowability when compared to the control mixture. This mix may not enhance flowability as LP does.

The 20 % of CKC shows V-funnel time of 9,8 sec, and the 30 % CKC time was 11,6 sec.

Increasing the percentage of CKC content results in extended in V-funnel flow time, suggesting reduction in workability. 20 % GGBS show V-funnel time of 6,2 sec; it was the highest level of flowability compared to the other mixtures. The pozzolanic properties of the material may help to improve its ability to flow. The flowability of a ternary combination of LP and CKC is improved compared to CKC alone, but not as greatly as LP alone. The given phenomena suggest the presence of a condition of balance between the two substances.

The ternary blend of 10 % CKC and 20 % GGBS indicates a V-funnel of 7,9 sec; this mixture preserves excellent flowability, suggesting that GGBS can counterbalance the adverse impact of CKC on flow rates. 10 % LP 20 % GGBS mix maintains excellent flowability, demonstrating the synergistic impact of LP and GGBS improving workability.

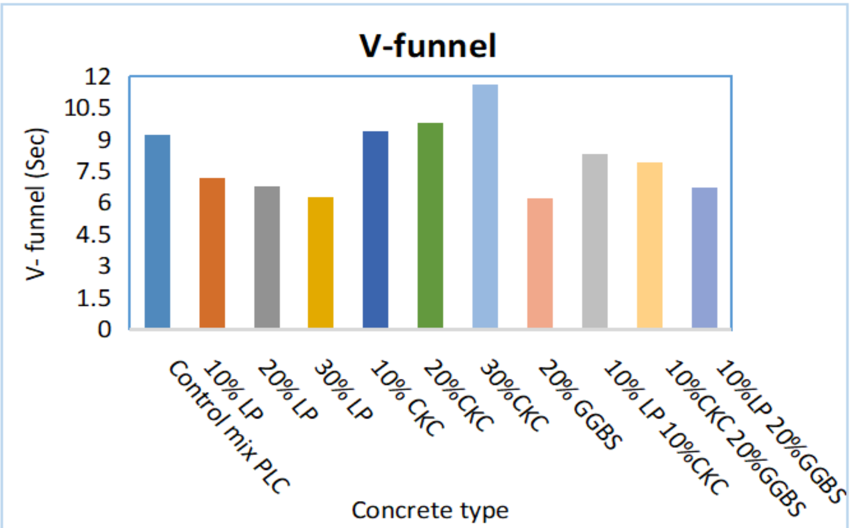


**Figure 9.** V-Funnel Flow Time for binary and ternary LWSCC mixes

*L-Box height ratio*

Passing ability is the capacity of concrete to flow through restricted spaces and narrow holes due to its weight. The assessment was conducted utilizing L-box test for fresh concrete mixtures. The ratio of (h2/h1) denotes the passing ability (PA). Results of the L-box test are presented in figure 10. The results in figure 4 indicated that the L-box height ratios varied from 0,887 to 0,987 for binary and ternary blends of LWSCC mixes using CKC, LP, and GGBS as substitutes for Portland cement. All LWSCC mixtures composed of binary and ternary blends of CKC, LP, and GGBS were categorized as PA2 (H2/H1 ≥ 0,80 for three bars) regarding their passing potential. The mixtures in this category had a satisfactory passing ability, above 0,8, which is deemed the minimum critical value as per (EFNARC, 2005). Baban et al.[34] confirmed these results. Figure 4 illustrates that the binary mixtures (10 % CKC, 20 % CKC, 30 % CKC) exhibited diminished passing ability relative to the control mix, with reduction of around (1,50, 3,87, 4,41)% respectively. It was noticed that this impact decreased with the 10 % LP, 20 % LP, 30 % LP, and 20 % GGBS and ternary mixes as shown in figure 4. The ternary mix with 10 % CKC 10 % LP shows same value of control mix 0,928 while the mix with 10 % CKC 20 % GGBS and 10 % LP20 % GGBS show increase by 1,93, 5,92 % respectively. Other researcher noted similar results.[35,36,37,38]

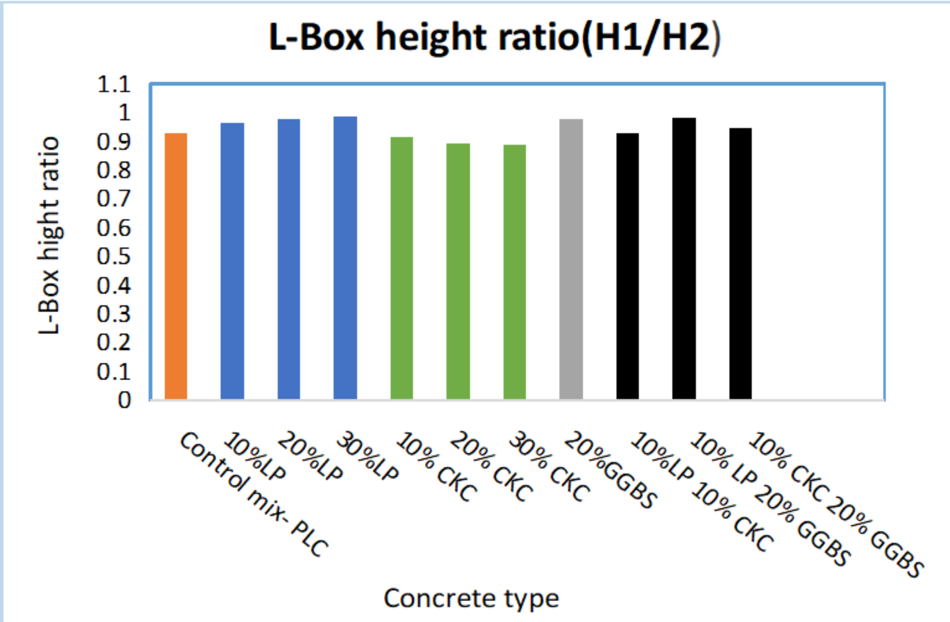


**Figure 10.** L-Box height ratio for LWSCC mixes

*Segregation resistance*

The LWSCC ability to preserve uniformity during transportation and placement. Sieve segregation resistance test is applicable to evaluate segregation resistance of LWSCC mixes. Slump flow test can also be visually assessed.

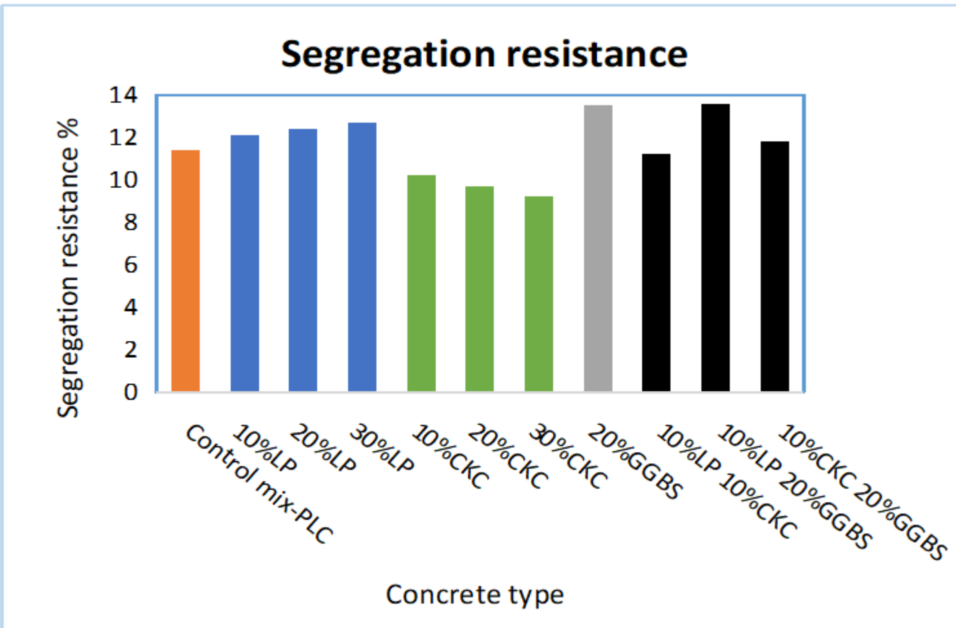


**Figure 11.** Segregation resistance for LWSCC

https://doi.org/10.56294/sctconf20251546

The results presented in figure 11 indicate that the segregation rate for all combinations was satisfactory, ranging from 9,2 % to 13,6 % which aligns with the criteria established by EFNARC (2005) that defines a segregation rate of < 15 % as SR2 class.

The binary combination (10 % CKC, 20 % CKC, 30 % CKC) exhibit lower segregation resistance than the control mix. The decrease in the percentages for the previously mentioned binary mixtures were approximately (10,52, 14,9, 19,29)% respectively.

The binary and ternary mixtures (10 %LP, 20 %LP, 30 %LP, 20 %GGBS, 10 % CKC 20 % GGBS, 10 % LP 20 %GGBS) exhibited better segregation resistance, with the segregation percentages increasing by (6,14, 8,77, 11,40, 18,40, 3,50, 19,29) respectively, compared with the reference mixtures as shown in figure 11.

**Hard Properties Results and Discussion**

*Bulk Density*

The control mix (PLC) has maximum bulk density values at 7 days of 1835 kg/m3 and 1847 kg/m3 at 28 days. When the replacement level of LP rises from 10 % to 30 %, it lowers the bulk density of the concrete from 1820 kg/m3 to 1787 kg/m3 at 7 days and from 1834 kg/m3 to 1796 kg/m3 at 28 days. Like LP, CKC equally results in a reduction in bulk density as the percentages of CKC increase. The density of the 10 % CKC mix is 1807 kg/m3, which is more advantageous than that of higher percentages, while the 30 % CKC mix exhibits the lowest density (1767 kg/m3) at both ages, probably because LP has a lower density than Portland cement.

Blends incorporating 20 % (GGBS) shows bulk density of 1873 kg/m3 at 7 days and 1887 at 28 days, as shown in figure 12. Compared to all other mixtures, showing that GGBS significantly improves the density and strength of concrete. This phenomenon can be due to the pozzolanic activity of the material and the subsequent development of supplementary binding phases.[39]

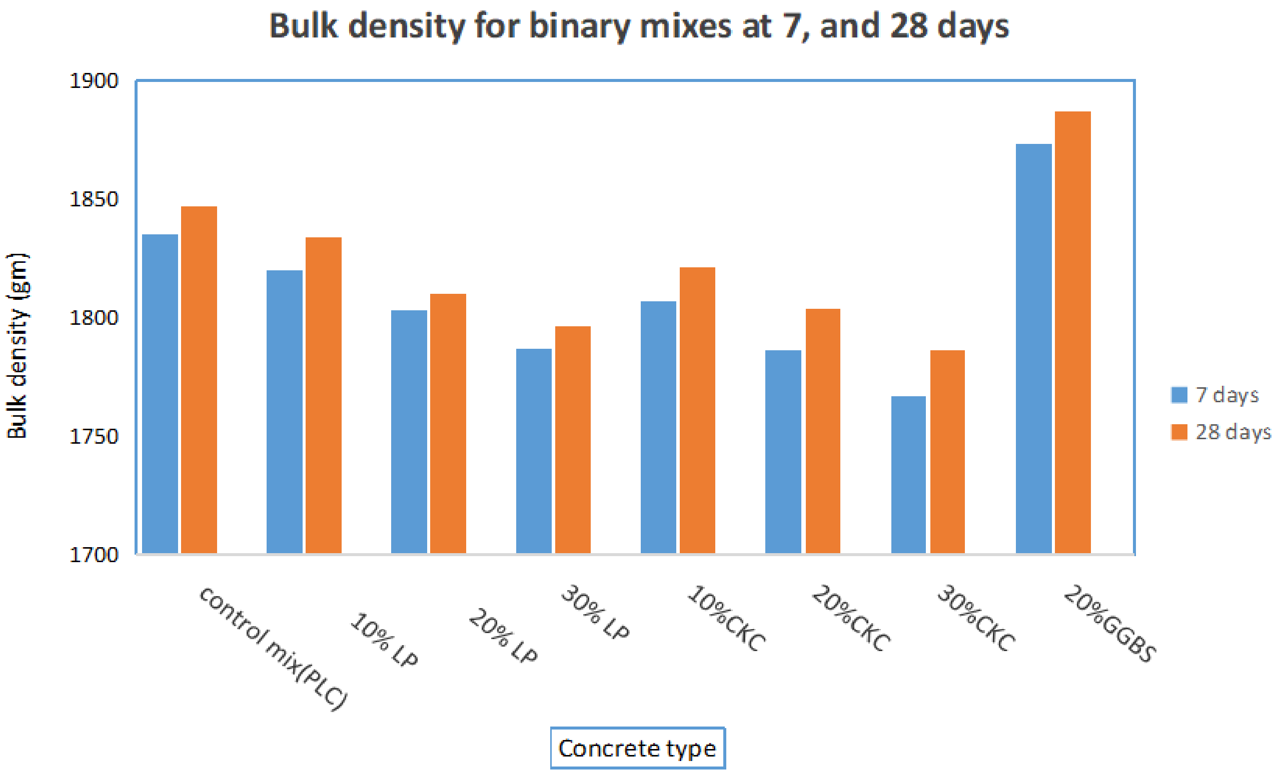


**Figure 12.** Bulk density for binary mixes at 7, and 28 days

At time points 7, and 28 days, the 10 % LP and 10 % CKC mix has the lowest density.

The addition of limestone powder (LP) and calcined kaolin clay (CKC) might be effect on the structure and cohesion within the mixture, resulting in a reduced density.

The mix of 10 % LP and 20 % GGBS, at 7 days and 28 days, has the greatest density. The use of GGBS facilitates increased compaction and hydration, therefore resulting in greater overall density.

10 % CKC 20 % GGBS, this mix, like the one before it, also derives advantages from the incorporation of GGBS, leading to increased densities in comparison to mixes lacking it. Although the CKC may provide supplementary advantage, its total impact is rather inferior to that of the LP and GGBS combination, as shown in figure 13.

https://doi.org/10.56294/sctconf20251546

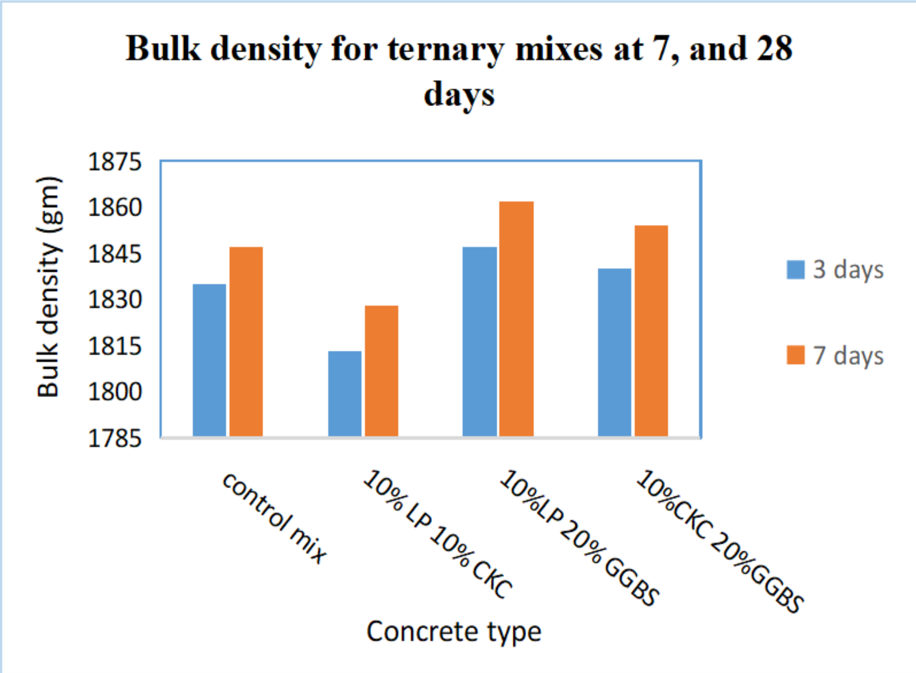


**Figure 13.** Bulk density for ternary mixes at 7, and 28 days

**Compressive strength**

*Binary mixes*

The control mixture (PLC) shows a steady increase in strength, achieving 48,7 Mpa after 90 days. This functions as a reference point for assessing the effectiveness of various mixing methods.

Compressive strength decreases when cement is replaced by 10 % LP, especially in the early ages, after three days, the control mix's compressive strength reduces to 23,2 Mpa, while the 20 % LP mix and 30 % LP mix drop to 22,3 Mpa and 20,1 Mpa, respectively.

Since LP functions more as filler than a binder, its reduced reactivity when compared to Portland cement is the cause of the drop in early age strength. The strength reduction is less significant at later ages (28 days, 56 days, and 90 days), though, showing that LP's pozzolanic reaction might eventually help in the development of strength. The 20 % PL mix 28 day compressive strength is 41,8 Mpa, a slight reduction from the control mix 43,6 Mpa.

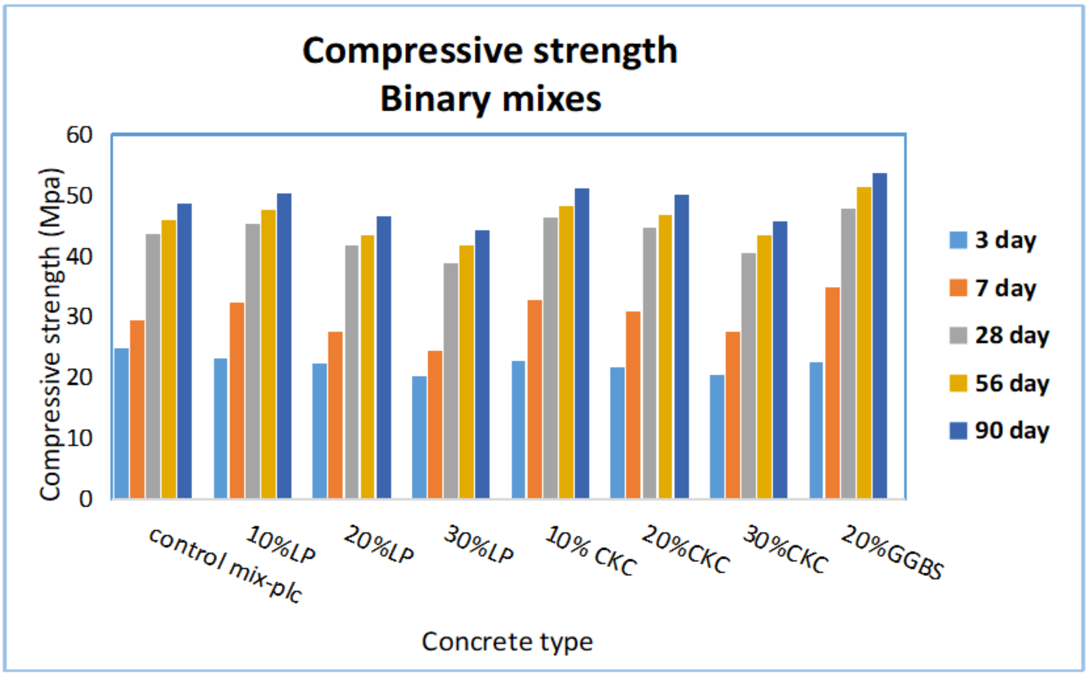


**Figure 14.** Compressive strength for binary mixes of LWSCC

https://doi.org/10.56294/sctconf20251546

Using CKC at concentrations of 10 % and 20 % enhances strength after 28 days, in contrast to higher percentages (30 %CKC) which result in reduced compressive strengths.

The 20 % GGBS mixture regularly exhibits excellent performance, achieving the maximum strength of 53,6 Mpa after 90 days. GGBS enhances long-term strength by reason of its pozzolanic characteristics, which facilitate improved binding and hydration mechanisms over an extended period (figure 14).

*Ternary mixtures*

The control mix demonstrates a consistent rise in strength, to its highest point of 48,7 MPa at 90 days. This demonstrates the efficacy of regular Portland cement in attaining strength over time.

10 % LP, also 10 % CKC: this mixture begins with a compressive strength of 22,6 MPa at 3 days and exhibits substantial growth, reaching 52,3 MPa by 90 days. The incorporation of limestone powder (LP) and calcined kaolin clay (CKC) seems to improve long-term strength.

10 % LP 20 % GGBS: this mixture exhibits shows improvement in the initial stages, ultimately achieving a compressive strength of 54,3 MPa at 90 days. The use of (GGBS) probably enhances strength development over time.

10 % CKC and 20 % GGBS: this mixture demonstrates a steady increase, reaching 55,2 MPa at 90 days. The amalgamation of CKC and GGBS appears to be efficacious in augmenting both initial and sustained strength.

In summary, although the control mix demonstrates consistent strength development, the mixes including alternative ingredients (LP, CKC, GGBS) display differing levels of enhanced strength over time, especially evident at 90 days of age. The results indicate that employing combination of these components can improve performance in concrete mixtures, rendering them viable alternatives for sustainable construction methods.(40,41,42)

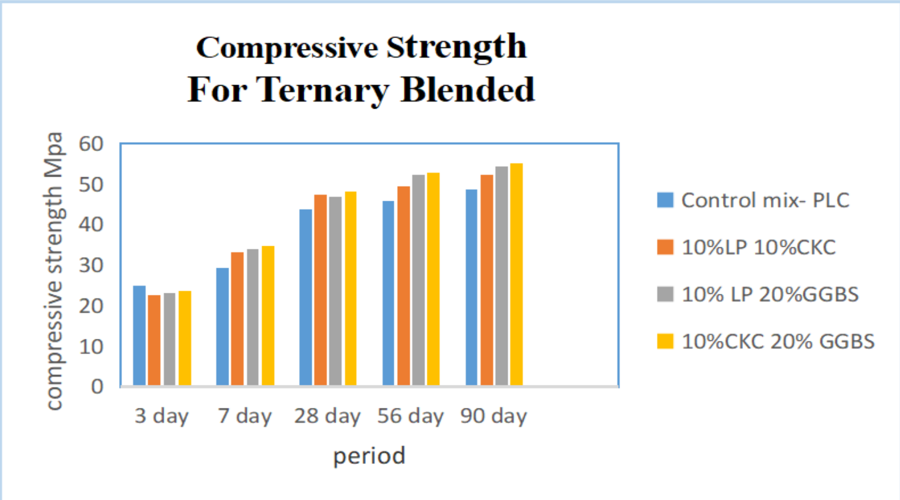


**Figure 15.** Compressive strength (Mpa) for Ternary mixes

**Statistical Analysis for Compressive Strength Results**

*Statistical analysis for compressive strength results for binary mixes*

Table 14 shows that the ANOVA results show that curing time significantly affects compressive strength, with an F-value (F = 676,7408) greater than the critical F-value (F-critical = 2,714076). The P-value (P = 2,06E-27) is below 0,05, confirming the effect of curing duration on strength development. Longer curing times enhance the hydration and improve the microstructure of binary mixes. Cause increase in compressive strength over time. Similarly, mix type significantly influences compressive strength, with an F-value (F = 23,35355) exceeding the critical F-value (F-critical = 2,35926). The P-value (P = 4,19E-10) is also below 0,05, indicating that the differences in strength between mix types are statistically significant. The variations in mix composition impact the strength development of binary mixes.

**Table 13.** ANOVA analysis compressive strength results for binary mixes

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **F crit** |
| Rows | 4212,567 | 4 | 1053,142 | 676,7408 | 2,06E-27 | 2,714076 |
| Columns | 254,399 | 7 | 36,34271 | 23,35355 | 4,19E-10 | 2,35926 |
| Error | 43,5735 | 28 | 1,556196 | | | |
| Total | 4510,539 | 39 | | | | |

**Statistical analysis for compressive strength results for ternary mixes:**

Table 13 shows that the ANOVA results show that curing time significantly affects compressive strength, with an F-value (F = 240,297354) greater than the critical F-value (F-critical = 3,259167). The P-value (P = 2,43E-11) is below 0,05, confirming the effect of curing duration on strength development. Longer curing times enhance the hydration and improve the microstructure in ternary mixtures, cause to increase in compressive strength over time. Similarly, mix type significantly influences compressive strength, with an F-value (F = 7,265039) exceeding the critical F-value (F-critical = 3,490295). The P-value (P = 0,0049) is also below 0,05, indicating that the differences in strength between mix types are statistically significant. The variations in mix composition impact the strength development of ternary mixes.

**Table 14.** ANOVA analysis compressive strength results for ternary mixes

| ANOVA | | | | | | |
|---|---|---|---|---|---|---|
| **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **F crit** |
| Rows | 2483,313 | 4 | 620,8283 | 240,297354 | 2,43E-11 | 3,259167 |
| Columns | 56,3095 | 3 | 18,76983 | 7,265039 | 0,0049 | 3,490295 |
| Error | 31,003 | 12 | 2,583583 | | | |
| Total | 2570,626 | 19 | | | | |

## CONCLUSIONS

The objective of the work was to determine the effectiveness of using (CKC) and (LP), together with (GGBS), as binary and ternary binders in (LWSCC).

The efficient application of binary and ternary combinations of waste materials (LP, CKC, and GGBS) in the production of LWSCC has been demonstrated. Concerning fresh properties, the replacement with CKC reduced the slump flow; however, the substitution of LP and 20 % GGBS in binary mixtures enhanced slump flow. New attributes negatively impacted by partial substitution of CKC in binary mixtures. Ternary blends demonstrated more pronounced effects than binary combinations, resulting in a reduction of V-funnel and slump flow, except for the ternary mix including 10 % LP and 20 % GGBS; which decreased V-funnel values while increasing slump flow. CKC typically exhibits plate-like particle morphology, leading to increased inter-particle friction. This design disrupts the smooth flow of the concrete mixture, necessitating additional water for the CKC mix to achieve comparable workability to a mixture that does not require it. The GGBS material has a more spherical shape than CKC, hence reducing inter-particle friction and improving flowability. GGBS hydrates with water to generate compounds that improve the workability and cohesiveness of the mixture, hence increasing its flow. LP works as a filler, minimizing pore volume in the mixture of concrete, therefore improving the flowability by facilitating a seamless transition for particles to pass each other, and the utilization of LP enhances the distribution of particle sizes, hence increasing packing density and decreasing the total water requirement. The inclusion of LP can enhance the fluidity of the mixture, but, when mixed with CKC, the advantageous impacts can be canceled out by the impact of CKC on cohesion.

The density of binary mixes decreased at 7 and 28 days compared to control mix, except the mixture with 20 % GGBS, its density was higher than control mixture and considered the highest density among all the binary and ternary mixtures. The binary mixtures with 30 % CKC and with 30 % LP demonstrated the lowest bulk density. The ternary and binary mixtures with CKC and LP shows the lowest specific gravity compared to cement caused this trend.

The binary blend of SCC mixtures, including 10 % LP, 10 % CKC, and 20 % GGBS, demonstrated enhanced compressive strength at all curing times. Nonetheless, mixture containing 30 % LP exhibited a notable reduction in compressive strength relative to other combinations. All ternary mixtures surpassed binary blends and control mixtures regarding compressive strength.

## BIBLIOGRAPHIC REFERENCES

1. A. Adesina, & P. Awoyera, (2019). Overview of trends in the application of waste materials in self-compacting concrete production. SN Applied Sciences (2019) 1:962. https://doi.org/10.1007/s42452-019-1012-4.

2. V. Revilla-Cuesta, M. Skaf, F. Faleschini, J.M. Manso, V. Ortega-López, Self-compacting concrete manufactured with recycled concrete aggregate: An overview, Journal of Cleaner Production. Volume 262, 20 July 2020, 121362. https://doi.org/10.1016/j.jclepro.2020.121362.

3. R. H. Faraj, R. F. H. Ali, A. F. H. Sherwani, B. R. Hassan, & H. Karim, (2020). Use of recycled plastic in self-compacting concrete: A comprehensive review on fresh and mechanical properties. Journal of Building Engineering. Volume 30, July 2020, 101283. https://doi.org/10.1016/j.jobe.2020.101283.

4. K.M.A. Hossain, (2015). Lightweight SCC with volcanic and other natural materials. Proceedings of the Institution of Civil Engineers-Construction Materials, 168(1): 35-44. https://doi.org/10.1680/coma.14.00013.

5. T. Sonia, R. Subashini, (2016). Experimental investigation on mechanical properties of light weight concrete using leca. International Journal of Science and Research, 5(11): 1511-1514.

6. M. K.Yew, M.C.Yew, J.H. Beh, (2020). Effects of recycled crushed light expanded clay aggregate on high strength lightweight concrete. Materials International, 2(3): 0311-0317. https://doi.org/10.33263/Materials23.311317.

7. A. Ardakani, M. Yazdani, (2014). The relation between particle density and static elastic moduli of lightweight expanded clay aggregates. Applied Clay Science, 93: 28- 34. https://doi.org/10.1016/j.clay.2014.02.017

8. M. Yoon, G. Kim, G.C. Choe, Y. Lee, T. Lee, (2015). Effect of coarse aggregate type and loading level on the high temperature properties of concrete. Construction and Building Materials, 78: 26-33. https://doi.org/10.1016/j.conbuildmat.2014.12.096

9. J. J. Chen, P. L. Ng, A.K.H.Kwan, & L. G. Li, (2019). Lowering cement content in mortar by adding superfine zeolite as cement replacement and optimizing mixture proportions. Journal of Cleaner Production, 210, 66-76. https://doi.org/10.1016/j.jclepro.2018.11.007.

10. K. Tan, Y. Qin, T. Du, L. Li, L. Zhang, & J. Wang, (2021). Biochar from waste biomass as hygroscopic filler for pervious concrete. Construction and Building Materials Volume 287, 14 June 2021, 123078. https://doi.org/10.1016/j.conbuildmat.2021.123078.

11. R. Vinoth, & M. V. Kumar, (2020). Strength and durability performance of Light Weight Self-Compacting Concrete (LWSCC) with Light Expanded Clay Aggregate (LECA). In IOP Conference Series: Materials Science and Engineering (Vol. 872, No. 1, p. 012104). DOI 10.1088/1757-899X/872/1/012104.

12. Q. L. Yu, D. J. Glas, & H. J. H. Brouwers, (2020). Effects of hydrophobic expanded silicate aggregates on properties of structural lightweight aggregate concrete. Journal of Materials in Civil Engineering 32(6):06020006. https://doi.org/10.1061/(ASCE)MT.1943-5533.0003198.

13. A. Abdalqader,& M. Sonebi, (2022). Recent development and future trends in self-compacting concrete. In Inst. Concr. Technol. Annu. Tech. Symp (pp. 1-23).

14. Ž. Rudžionis, S. K. Adhikary, F. C. Manhanga, D. K. Ashish, R. Ivanauskas, G. Stelmokaitis, & A. A. Navickas, (2021). Natural zeolite powder in cementitious composites and its application as heavy metal absorbents. Journal of Building Engineering, 43, 103085. https://doi.org/10.1016/j.conbuildmat.2023.133766.

15. Eman Hasan Raheem and Haider M.Owaid, (2024). The Effect of Various Contents of Nano- Lime on The Properties of Self-Compacting Geopolymer Concrete Containing Micro-Steel Fibers.Salud, Ciencia y Tecnología – Serie de Conferencias. 2024; 3:837 https://doi.org/10.56294/sctconf2024837.

16. S. K. Adhikary, Ž. Rudžionis, & S. Tučkutė, (2022). Characterization of novel lightweight self-compacting cement composites with incorporated expanded glass, aerogel, zeolite and fly ash. Case Studies in Construction Materials, Volume 16, June 2022, e00879. https://doi.org/10.1016/j.cscm.2022.e00879

17. I. S. Agwa, O. M. Omar, B. A. Tayeh, & B. A. Abdelsalam, (2020). Effects of using rice straw and cotton stalk ashes on the properties of lightweight self-compacting concrete. Construction and Building Materials, 235, 117541. https://doi.org/10.1016/j.conbuildmat.2019.117541.

18. N. Hilal, N. Hamah Sor,& R. H. Faraj ,(2021). Development of eco-efficient lightweight self-compacting concrete with high volume of recycled EPS waste materials. Environmental Science and Pollution Research, 28(36), 50028-50051. https://doi.org/10.1007/s11356-021-14213-w

19. IQS. No. 5: For Portland Cement. Central Agency for Standardization Quality Control, Planning Council Baghdad, IRAQ; 1984.

20. EFNARC. European Guidelines for Self-Compacting Concrete, Specification and Production and Use, Association House, U.K. 2005.

21. raqi Standard Specification, no 807/1988 “Lime That Used in Building”.

22. Robin Phinney, Kelly Graham, Kevin Graham,Burl Aycock. 2007.method of producing metakaolin

23. ASTM C 618 – 03, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.

24. J. Ahmad, K. J. Kontoleon, A. Majdi, M. T. Naqash, A. F. Deifalla, N. Ben Kahla, ... & S. M. Qaidi, (2022). A comprehensive review on the ground granulated blast furnace slag (GGBS) in concrete production. Sustainability, 14(14), 8783. https://doi.org/10.3390/su14148783.

25. IQS No.45 (1984). for Aggregates of Natural Resources used for Concrete and Construction. Baghdad, Iraq.

26. ASTM C330/C330M-17 Standard Specification for Lightweight Aggregates for Structural Concrete.

27. ASTM C494 (2005) : Standard specification for chemical admixtures for concrete. West Conshohocken, PA, USA: ASTM.

28. Masoud Dadkhah, Reza Rahgozar, Ali Bandani, Peyman Rahgozar (2023). Mechanical Properties of Self-Compacting Lightweight Concrete Containing Pumice and Metakaolin. https://doi.org/10.22075/jrce.2023.29150.1762

29. Güneyisi, E., Gesoğlu, M., Altan, İ., & Öz, H. Ö. (2015). “Utilization of cold bonded fly ash lightweight fine aggregates as a partial substitution of natural fine aggregate in self-compacting mortars”. Construction and Building Materials, 74, 9-16.

30. B.S.1nstitutions, Method for determination of compressive strength of concrete cubes. London BS, 1881 Part 116. 1983.

31. Mohd Afiq Mohd Fauzi, Muhd Norhasri Muhd Sidek, Ahmad Ruslan Mohd Ridzuan. Effect of Limestone Powder as an Additive and as Replacement of Self-Consolidating Lightweight Foamed Concrete. Sustainable Construction and Engineering Technology.DOI: https://doi.org/10.30880/ijscet.2020.11.01.024.

32. Okan Karahan, KhandakerM.A. Hossain, Erdogan Ozbay, Mohamed Lachemi, Emre Sancak. Effect of metakaolin content on the properties self-consolidating lightweight concrete. Construction and Building Materials. Volume 31, June 2012, Pages 320-325.

33. Abdallah Adnan Abdallah Al-Oran, Nor Azizi Safiee, Noor Azline Mohd Nasir. Fresh and hardened properties of self-compacting concrete using metakaolin and GGBS as cement replacement. September 2019 European Journal of Environmental and Civil engineering 26(2):1-14. https://doi.org/10.1080/19648189.2019.1663268.

34. Baban Jamal Hamasalh1&Bahman Omar Taha2&Ganjeena Jalal Khoshnaw. Fresh Properties of Lightweight Concrete and Lightweight Self Compacting Concrete Produced with Pumice Aggregate. Eurasian Journal of Science & Engineering ISSN 2414-5629 (Print), ISSN 2414-5602. Volume 6, Issue 2; December, 2020.

35. Gholhaki, M., Hajforoush, M., & Kazemi, M. (2018). “An investigation on the fresh and hardened properties of self-compacting concrete incorporating magnetic water with various pozzolanic materials”. Construction and Building Materials, 158, 173–180

36. Kadhum, A. O., & Owaid, H. M. (2020). Experimental Investigation of Self Compacting High Performance Concrete Containing Calcined Kaolin Clay and Nano Lime. Civil Engineering Journal, 6(9), 1798-1808

37. Joshaghani, A., Balapour, M., Mashhadian, M., & Ozbakkaloglu, T. (2020). Effects of nano-TiO2, nano-Al2O3, and nano-Fe2O3 on rheology, mechanical and durability properties of self-consolidating concrete (SCC): An experimental study. Construction and Building Materials, 245, 118444.

38. Faez, A., Sayari, A., & Manie, S. (2020). Mechanical and rheological properties of self-compacting concrete containing Al2O3 nanoparticles and silica fume. Iranian Journal of Science and Technology, Transactions of Civil Engineering.

39. Choudhary, R., Gupta, R., & Nagar, R. (2020). "Impact on fresh, mechanical, and microstructural properties of high strength selfcompacting concrete by marble cutting slurry waste, fly ash, and silica fume". Construction and Building Materials, 239, 117888.

40. Frieh, K. J., Abbas, W. A., & Hamid, M. M. (2014). Some Properties of Concrete Containing High Fraction Volume of Metakaolin. Engineering and Technology Journal, 32(1),230-248.

41. Kannan, V., & Ganesan, K. (2014). Chloride and chemical resistance of self compacting concrete containing rice husk ash and metakaolin. Construction and Building Materials, 51, 225-234.

42. Tariq, S., Scott, A. N., Mackechnie, J. R., & Shah, V. (2020). Durability of high volume glass powder self-compacting concrete. Applied Sciences, 10(22), 8058.

## FINANCING
No financing.

## CONFLICT OF INTEREST
The authors declare that there is no conflict of interest.

## AUTHORSHIP CONTRIBUTION
*Data curation:* Shimoos Hussain Alsaady, Haider M. Owaid.
*Methodology:* Shimoos Hussain Alsaady, Haider M. Owaid.
*Software:* Shimoos Hussain Alsaady, Haider M. Owaid.
*Drafting - original draft:* Shimoos Hussain Alsaady, Haider M. Owaid.
*Writing - proofreading and editing:* Shimoos Hussain Alsaady, Haider M. Owaid.