Jurnal Kejuruteraan 37(7) 2025: 3493-3503
https://doi.org/10.17576/jkukm-2025-37(7)-28

Properties of Lightweight Concrete by Incoporating Coarse Lightweight Expanded Clay Aggregate with Chemical Additives

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Received 7 February 2025, Received in revised form 24 July 2025
Accepted 24 August 2025, Available online 30 October 2025

ABSTRACT

Concrete, a primary construction material, is typically composed of cement, sand, gravel, and water, which combine to produce a durable and robust material. In traditional concrete, natural resources, such as fine and coarse aggregates, are often sourced from quarries. Quarrying involves blasting rock into smaller fragments, especially to produce coarse aggregates for industrial construction. However, this extraction process has significant environmental repercussions, including habitat disruption and resource depletion. To address these issues, materials like Lightweight Expanded Clay Aggregate (LECA) have been explored as sustainable alternatives to conventional aggregates. LECA can reduce the environmental impact associated with quarrying by decreasing the reliance on natural resources. However, previous studies have shown that using LECA as a replacement for coarse aggregate tends to increase water absorption, which can negatively impact the compressive strength of concrete. This study aimed to improve the performance of lightweight concrete by substituting coarse aggregates with LECA and enhancing the mixture with sodium silicate (SS). By varying the proportions of sodium silicate alongside LECA, this research evaluated the impact on concrete properties through lab tests, including slump, compressive strength, water absorption, and density assessments. Results revealed that the inclusion of sodium silicate in the LECA-based mix yielded a 42.5% increase in compressive strength, a 20% reduction in slump, a 97.3% reduction in water absorption, and a 46.3% reduction in density compared to control samples. These findings contribute valuable insights into concrete technology, supporting SDG 9 by promoting sustainable, innovative practices in the Malaysian construction industry.

Keywords Lightweight concrete; LECA balls; sodium silicate; SDG2030; sustainable construction

INTRODUCTION

Concrete is a basic material in construction that contains a mixture of cement, sand, aggregate and water that has been used a long time ago. Concrete has good mechanical properties, but it is heavy due to all the dense material (Ibrahim & Atmaca 2023). Its strength to weight ratio is quite low among construction material (Jhatial et al. 2021). Concrete has strong resistance, durable and cheap compared to using steel. Design in concrete production is advancing year by year. To produce concrete, it must be according to the purpose of what we want to produce, such as how much the content of the mixture is for an application, and it is necessary to choose the correct concrete composition according to the standards in order to avoid the waste of design materials or the term can be called 'overdesign'. In the anatomy of concrete, each breakdown such as sand, aggregation, cement, water and additives must be emphasized on the quantity where it will affect the concrete.

The components of aggregate such as coarse aggregate are obtained from quarry work such as in forests and hilly areas. The results of this quarry work have had many negative impacts on the environment such as flora and fauna and environmental pollution such as haze (Chin et al. 2019). For example, when quarrying works against forests that nearby the rivers, it will result in changes in the existing movement of surface water and underground water and disrupt the recharge of natural water which may result in flooding. It also disrupts drinking water quality for residents and wildlife near or downstream from the quarry site. In order to deal with or reduce pollution, damage and achieving sustainability and innovation in construction, this study employed modern construction technology by substituting conventional coarse aggregates, typically quarried stone, with Lightweight Expanded Clay Aggregates (LECA). When using LECA as a substitute for coarse aggregate, it will reduce the weight of the lightweight concrete (LWC). The major benefits of LWC are that its low density properties incorporate of porous lightweight aggregate (Mehrab & Esfahani 2022; Lutfi et al. 2020).

LECA is a potato-shaped due to the circular movement of the kiln. In LECA Particles, there are holes of different sizes. Physically LECA is dark brown, reddish or red-brown. There are various colors in yellow or black. This color variation may be related to the various chemical compositions of LECA and its manufacturing process. It is a harmless chemical that is inert and lightweight, possesses a natural pH value near 7, is impermeable to moisture, non-flammable, non-biodegradable, and remains stable under harsh temperatures. It possesses superior thermal insulation, fire resistance, and soundproofing owing to its elevated acoustic resistance. LECA is a very flexible material with a wide range of applications. For example, it can be widely used in the construction industry to produce lightweight blocks, concrete, precast as well as structural backfills on foundations (Gradinaru et al. 2018;Vijayalakshmi & Ramanagopal 2018).

Quarry is work where large stones or minerals are taken out of the ground. Large-scale rock or dirt excavation, drilling, or blasting are common methods used to produce quarries. Quarries can provide a variety of materials especially can be used in construction. Quarries come in many sizes, from modest operations for neighborhood use to large operations that create materials for industrial use. However, quarrying has had many side effects on the environment.

Problems such as dust and cracks in the infrastructure due to stone fragments from the blasting work have occurred and are worrying the residents of the housing. Residents in Sungai Ara, Penang have urged the relevant parties against the quarry work where the activity of breaking stone blocks has caused the residential area to experience various incidents, including cracks in the walls of houses and floors and dust. In addition, they often hear unusually loud explosions, believed to be from the stone quarry project involved (Sajedi & Shafigh 2012). Residents of Nibong Tebal in Penang have complained that the quarrying incident in Batu Kawan has affected the health of nearby residents which can cause breathing problems such as shortness of breath, asthma and even skin diseases (Mortazavi & Majlessi 2012). The contractor or construction company must do an Environmental Impact Assessment or better known as Environmental Impact Assessment (EIA) before doing this kauri project. Environmental Impact Assessment (EIA) is a valuable factor in promoting sustainable development, protecting the environment, and ensuring that proposed development is socially and economically feasible. In most cases, it is necessary to follow laws or regulations for projects that can have a significant negative impact on the environment. Based on the occurrence, it cannot be disputed that the exploitation of natural resources has a major influence on society. Studies reveal that the construction sector has the greatest potential to cut greenhouse gas emissions at a fair cost (Hatungimana et al. 2019). The evaluation of environmental advantages derived from utilizing recycled materials in standard construction components is often conducted through Life Cycle Assessment, focusing on primary embodied energy and greenhouse gas emissions, employing a "Cradle-to-gate" methodology. (Ho et al. 2023; Ahmad Syauqi et al. 2024).

LECA was produced from a unique plastic clay that contains no lime. The clay is heated to a very high temperature of about 1100 to 1300 □ in a rotary kiln where it is dried and fired. Although the burning organic chemicals cause the pellet to expand or swell, it will form a ceramic pellet with a porous material, lightweight and high crushing resistance. During heating, gas is produced in the pellet and is trapped in it after cooling. LECA particles include linked voids of varying dimensions. Other varieties have various structures and geometries. The study's results rely on the manufacturing procedure, which boosts the temperature during sintering to an increase in the amount of porosity and generates continuous pores. A rise in temperature above the pyro-plastic range will produce a decline in pore size and porosity (Dordio & Carvalho 2013). The LECA balls are shaped like potatoes or round due to the rotary kiln process. According to (Yip et al. 2022), from 0.1 to 25 mm LECA is available in various sizes depending on the manufacturing process suitable for both fine and coarse aggregates. The many air voids found within and between aggregates may be a contributing factor to LECA's ability. Depending on their size, LECA can range in loose bulk density from 250 to 710 kg/m^3 (Yip et al. 2022). Figure 1 shows the difference in the size of LECA produced which has the characteristics of each size has grown widely in the construction and materials industry (Rashad 2018). Figure 2 shows the shape of the size and cross-section containing air voids in LECA (Rashad 2018). A study developed an innovative type of mechanically stabilized earth (MSE) structure using geosynthetic tubes filled with lightweight expanded clay aggregates, reinforced with geosynthetic layers. Experimental investigations demonstrate how the stiffness of the geosynthetics influences tube behavior, specifically affecting load capacity, volume change, and cross-sectional stability (Buratti et al. 2016). Water absorption, specific gravity, pore structure and surface texture of expanded granules were studied in relation to clay type, firing temperature, amount and type of pore forming agent. In the results of the study, it has been found that the quality of LECA is greatly influenced by the type of clay, the type and quantity of pore-forming agents and the burning temperature (Ahmad & Chen 2019).

FIGURE 1. Sizes of LECA

FIGURE 2. Cross section air void in LECA

COMPRESSIVE STRENGTH

The quality of the clay used in the firing method and the size and shape of the pellets are just some of the variables that affect the compressive strength of LECA. LECA can also be used as a lightweight aggregate in concrete, which can improve its insulating properties and reduce its weight. According to previous studies, the strength of lightweight concrete using LECA is currently recorded at about 100 MPa with the addition of silica fume (SF) (Lutfi et al. 2020).

In the study of (Nkansah et al. 2012), the compressive strength of the control mixture without foam with 49.5% LECA at 28 days was 24.75 MPa, which is 14.75%, 35.5% and 51.3% higher than the LECA mixture containing 10%, 15% and 20 % foam volume or total volume of ECA 37.6%, 31.6% and 26% (Nkansah et al. 2012). The strength-density ratio of this mix is high and in the range of 14.20–17.87 which is 45% to 56% higher than normal weight concrete (NWC) (Röck et al. 2020). The additional use of sodium silicate has increased mortar strength by 63% using 5% sodium silicate (Lim et al. 2018). The compressive strength of the specimen for 42 days was 34.5 MPa without silica fume and 49 MPa was recorded with the addition of 25% silica fume (Bhogayata et al. 2020). An increase in compressive strength during the 14th day by using sodium silicate as much as 50% was used but on the 28th day the compressive strength suddenly decreases (Lutfi et al. 2020).

DESTINY

According to previous studies, an increase in LECA content from 30% to 40% resulted in a 12% reduction in the specific gravity content, meaning that the density value decreased (Handayani et al. 2022). In the production of lightweight concrete or geopolymer concrete has found a significant reduction in the density of the composite due to the use of LECA. In the another study, 100% replacement of natural aggregate with foam which reduces the density up to 54.18% with 1150 kg/m^3 (Wang et al. 2020). In the experiment, the use of LECA with an average size of 2–16 mm reduced the density in the range of 42-45% at 100% replacement of natural aggregate (Rashad 2018; Wang et al. 2020).

In addition, using of 20% volume and 50% volume of corn cob aggregate with the addition of sodium silicate resulted in a slight decrease in concrete density while the use of 80% volume of corn cob aggregate gave a slight increase (Rashad 2018). Sodium silicate can produce lightweight concrete with a lower density than normal concrete mixes when combined with LECA. In a previous study, the use of silica fume as much as 25% gave a density value of 1666 kg/m^3 compared to 1723 kg/m^3 without the addition of silica fume (Bhogayata et al. 2020). The higher the percentage value of silica fume replaced by cement, the lower the value of the density. However, the results of the study found that the addition of chemical treatment can reduce water absorption in low-density concrete (Haoxiang et al. 2021).

WATER ABSORPTION

The water absorption test against the use of LECA has increased due to the porous structure of the grain. Clay is heated at high temperatures to cause it to expand and create a porous structure with a high surface area to volume ratio. According to earlier research in a 24-hour absorption test conducted in conformity with ASTM C127 and C128, LECA aggregates will absorb 30% of the moisture contained in the dry aggregate mass. In addition, studies have indicated that substituting LECA has caused a 10% to 25% increase in water absorption (Lutfi et al. 2020). To reduce the rate of water absorption, the use of mineral materials such as silica fumes, fly ash and limestone jugs can solve this problem. They have a lower absorption value. In a study by (Górniak et al. 2015) the addition of silica fume gave an 11.93% reduction in water absorption in concrete. A total of 13.3% reduction in water absorption against the use of a mixture of sodium silicate with 8 molarity of sodium hydroxide (Ayati et al. 2018). Previous studies also found the use of additional sodium silicate is able to reduce the water absorption capacity in the use of corn cob grains from the range of 94% to 127% compared to without corn cob grain preservation (Rashad 2018; Kim et al. 2014).

In order to reduce carbon emissions and sustainability, LECA can reduce the impact on the environment and reduce the exploration of natural resources. However, according to previous studies that have been studied by researchers, the use of LECA as a substitute for coarse aggregate gives an increase in water absorption which has an impact on the decrease in the compressive strength of concrete (Ahmad Syauqi et al. 2024; Syed Mohamed & Lim, 2024). In this study, it will be conducted to study and improve the effectiveness of replacing coarse aggregate by using LECA together with Sodium Silicate as chemical additives to advance the mixing quality and produce a new basic framework in the construction sector in Malaysia in achieving the goals of sustainability and construction innovation.

MATERIAL AND EXPERIMENT METHODS

MATERIALS

ORDINARY PORTLAND CEMENT (OPC)

The OPC (CEM I 42.5N), was used as the concrete constituent material and chemical results are summarized in Table 1.

TABLE 1. Properties of Ordinary Portland Cement

Properties	OPC
Specific gravity	3.15
Specific surface area (m^2/kg)	365
SiO_2 (%)	21.00
AL_2O_3 (%)	5.31
Fe_2O_3 (%)	3.44
CaO (%)	65.00
MgO (%)	1.50
SO_3 (%)	0.26
Na_2O (%)	0.50
K_2O (%)	0.25

SILICA FUME (SF)

The silica fume used in this study is Elkem Microsilica grade 940D from the distribution agent Elkem Materials S.E.A. The use of this brand complies with standards such as EN 13263. The purpose of using silica fumes in this concrete mixture is to increase the strength and durability of concrete. Silica fume stored and used directly without chemical composition treatment is as in Table 2.

TABLE 2. Chemical composition of Silica Fume

Chemical Composition, %	Value
SiO_2	96.50
AL_2O_3	0.50
Fe_2O_3	0.23
CaO	0.30
MgO	0.20
C	0.75
SO_3	0.20
K_2O	0.50
Na_2O	0.30
Na_2O eq	0.50
LOI	1.70
Specific Gravity	2.2

FINE AGGREGATE

Fine aggregate usually uses river sand that is readily available in the laboratory. The size of the fine aggregate used is in the range that crosses the 4.75 mm sieve (no. 4) and remains in the position of the 75 µm sieve (no. 200).

COARSE AGGREGATE

CRUSHED AGGREGATE

Gravel is also used in this study as a coarse aggregate with a maximum size of 20 mm. These aggregates are also found naturally by crushing them during the quarrying process.

LECA BALLS

LECA balls are small, light and spherical in shape with a hard outer shell and a honeycomb-like which has high amounts of pores compare to normal aggregate. LECA balls are made by heating clay in a rotary kiln at a temperature of 1100-1200°C which causes the clay to expand and become porous which will produce a light and low-density aggregate. This LECA ball formation has many types of sizes depending on the production from the factory. The size used in this study is in the range of 10 - 20 mm. Table 3 shows the physical properties of LECA balls that have been determined from the results of previous studies (Nkansah et al. 2012).

TABLE 3. Physical properties of LECA balls

Physical Properties	LECA
Bulk Density, kg/m^3	433
Apparent Density, kg/m^3	525
Water Absorption, %	22.1
Compressive Strength, MPa	3.1
Loss On Ignition, %	0.06
Size, mm	10 -20

SODIUM SILICATE (SS)

The chemicals used in this study are Sodium Silicate in the form of a solution (in Table 4) obtained from Chemiz (M) Sdn. Bhd. The function of sodium silicate in lightweight porous aggregate is primarily as a chemical binder and pore-structure modifier, which enhances the mechanical properties and durability of the aggregate.

TABLE 4. Chemical properties of Sodium Silicate

Specification	Value
Alkaline (Na_2O)	16.5 – 18.5%
Silica (SiO_2)	34.0 – 37.0%
Molar Ratio ($SiO_2.Na_2O$)	1.90 – 2.30
Iron (Fe)	< 0.03%
Specific Gravity (20	57.0 – 59.0
Water Insoluble	<0.03%

MIX DESIGN

In this study, 25% of the coarse aggregate was replaced with LECA balls, and sodium silicate was added at dosages of 5%, 10%, and 20% as a chemical additive. The resulting mix designs were modified accordingly, and the concrete mix proportions were calculated based on the Department of Environment (DoE) method, as shown in Table 5 (Syed Mohamed & Lim 2024).

TABLE 5. Mix design

MIX	OPC (kg/m³)	Silica Fume (kg/m³)	Fine aggregate (kg/m³)	LECA (kg/m³)	Coarse aggregate (kg/m³)	Sodium Silicate (L/m³)	Water (L/m³)
Control (CC)	310	77	810	0	1267	0	209
LWC5%SS	310	77	810	317	950	19.4	209
LWC10%SS	310	77	810	317	950	38.7	209
LWC20%SS	310	77	810	317	950	77.4	209

SAMPLE PREPARATION

The sample mixtures are CC, LWC5%SS, LWC10%SS and LWC20%SS. CC is a control concrete. For lightweight concrete or LWC, the percentage refers to the value of the percentage of sodium silicate used in the concrete mix. Samples are provided in Table 6 as follows containing 7 and 28 days of curing in water. The mold used for this study, which is the compressive strength test, the water absorption test and the density test, only uses a cube mold with a size of 150 mm x 150 mm x 150 mm.

TABLE 6. Number of cubes

Sample	Mould
CC	6 Cubes
LWC5%SS	6 Cubes
LWC10%SS	6 Cubes
LWC20%SS	6 Cubes
Total	24 Cubes

LECA BALLS

\In this study, the dry LECA balls were soaked in a container containing clean water for 24 hours before the LECA balls were mixed with the mixed materials during concrete mixing. LECA balls have air voids that make the mass of the balls light. However, the presence of air voids in the aggregate causes the rate of water absorption to be high because it requires a lot of water to fill the area containing air voids against LECA balls. When soaking the LECA balls in water before mixing, this is to ensure that the LECA balls are in a saturated state which provides an improvement to the bond with the cementitious materials in the concrete mix, directly increasing strength and durability. In addition, this is also to avoid LECA balls absorbing water while mixing concrete (Heiza & Masoud. 2018).

TEST ON SAMPLE CONCRETE

Table 7 shows several tests carried out on concrete according to standard procedures to obtain the required properties.

TABLE 7. Testing Standards

Tests	Related Standards
Slump Test	BS EN 12350-2
Density	BS EN 12390-7:2009
Water Absorption	BS 1881:122
Compressive strength	BS EN 206

RESULTS AND DISCUSSION

SLUMP TEST

Figure 3 shows that the lightweight concrete sample, also known as LWC, had a much higher slump reading in comparison to CC. This can be attributed to the incorporation of LECA balls as a substitute for coarse aggregate, which possesses a better workability. The slump reading value of LWC5%SS is 150 mm, which is relatively high. The slump of LWC10%SS is 138 mm, while the slump of LWC20%SS is 128 mm. Upon comparison with the obtained value, it was discovered that the inclusion of sodium silicate % in the concrete mixture resulted in a reduction in the slump value. A drop in the slump value indicates that the workability of the concrete mix is compromised. Previous researchers have found that the incorporation of sodium silicate can enhance the workability of concrete (Taghvayi et al. 2018). Furthermore, these study's findings, together with earlier research, have demonstrated that concrete containing sodium silicate achieves complete hardening in a shorter period compared to concrete without sodium silicate. This is due to its ability to accelerate the chemical reaction that occurs during the cement hydration process. Sodium ions in sodium silicate enhance the reactivity of cement hydration, leading to an increased rate of reaction.

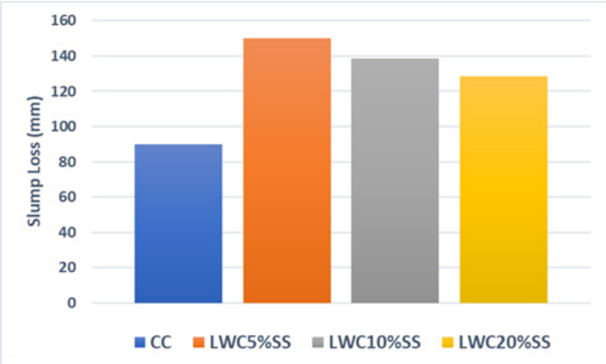

FIGURE 3. Slump loss of specimens

COMPRESSIVE STRENGTH

The study has yielded the average compressive strength value, which is depicted in Figure 4. Upon observing the concrete's age after 7 days of curing, the CC exhibited the maximum strength value of 18.39 MPa, surpassing the readings of other samples at the same curing age. LWC5%SS achieved the minimum reading of 6.71 MPa, which was lower than the readings of other varieties of lightweight concrete. LWC10%SS attained a measurement of 8.80 MPa and exhibited a 20.1% improvement in compressive strength compared to LWC20%SS, which measured 10.57 MPa. At the age of 28 days, the control concrete had a reading value of 28.9 MPa, which is the highest value recorded in this investigation. When comparing LWC20%SS samples at different curing ages, the sample cured for 28 days had a value of 14.12 MPa, which differed by 3.55% from the sample cured for 7 days. The compressive strength of LWC5%SS is 9.91 MPa, whereas LWC10%SS has a compressive strength of 12.45 MPa. The compressive strength at the age of 28 days of curing met the intended design target, in contrast to the age of 7 days. This is due to the extended curing period, which facilitates a more thorough hydration of cement and chemical reactions, resulting in a more robust concrete structure. Furthermore, Figure 5 illustrates the correlation between the compressive strength and the proportion of sodium silicate utilized in the concrete mixture. According to the graph, increasing the proportion of sodium silicate utilized results in a higher compressive strength. However, even with this increase, the compressive strength of the concrete is still relatively low compared to the control. The graph also indicates a marginal 2% to 3% rise in the disparity of compressive strength for each increment of sodium silicate use in the concrete mixture. A study found that the use of 5% sodium silicate in the mortar increased by 63% compared to prior research (Lim et al. 2018).

The inclusion of sodium silicate has led to an increase in compressive strength due to the adhesive qualities of silica gel present in sodium silicate, which has worked as a binding agent in the concrete matrix. It enhances the adhesion between cement particles, aggregates, and other components, hence strengthens the interfacial binding. Nevertheless, this study has shown that including lightweight concrete with LECA balls as part of the coarse aggregate has resulted in a marginal improvement compared to mortar.

DENSITY

Figure 6 shows the densities of LWC are significantly lower than CC. The slight disparity in density between the two curing ages can be mostly attributed to the duration of the hydration reaction and the processes of mixing and compaction. The study yielded control concrete density data of 2266 kg/m^3 at 7 days and 2340 kg/m^3 at 28 days. The LWC5%SS sample had a density of 1422 kg/m^3 after 7 days and 1318 kg/m^3 after 28 days.

The LWC10%SS exhibited a rise in density, with a measurement of 1659 kg/m^3 at 7 days and 1466 kg/m^3 at 28 days. The LWC20%SS lightweight concrete has achieved the highest recorded value in its category, measuring 1777 kg/m^3 after 7 days and 1600 kg/m^3 after 28 days. When comparing LWC20%SS (LWC) to CC, it was found that after 7 days of curing, LWC had a density that was 27.5% less than CC. After 28 days of curing, LWC had a density that was 46.3% less than CC.

Based on the evidence, it can be inferred that CC possesses a greater density compared to LWC because of the utilization of aggregate size and characteristics. For instance, various varieties of course aggregate, such as gravel and lightweight aggregate, specifically LECA balls, exhibit distinct densities. The investigation revealed that LECA balls possess lower density and a greater volume of air space, resulting in the overall LWC having a lower density value in comparison to the CC.

The incorporation of higher amounts of sodium silicate has had an impact on the density measurement of the concrete. This is because the increase in the composition of the materials in the concrete mixture leads to a corresponding rise in the weight of the concrete. Previous research studies have shown that the usage of light aggregate with Sodium Silicate might result in a drop in density ranging from 20% to 50% (Rashad 2018). Prior researchers have likewise seen no alteration to concrete when salt is included (Haoxiang et al. 2021). The density of concrete containing sodium silicate additive can be influenced by both external and internal factors, including the positioning of sodium silicate and the preparation procedure.

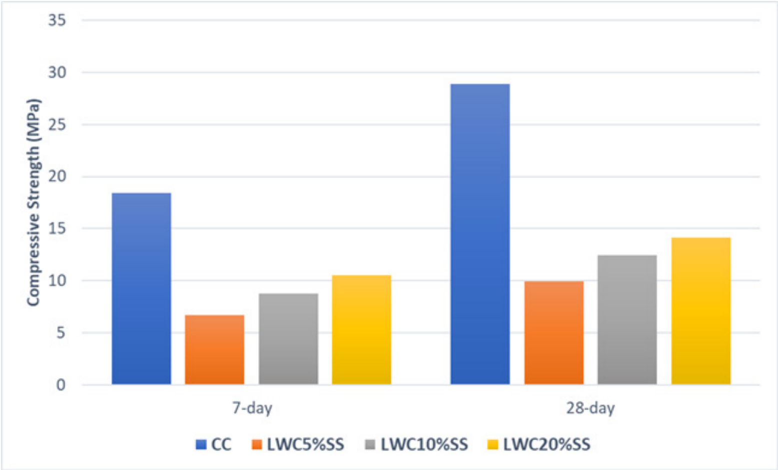

FIGURE 4. Compressive strength of concrete

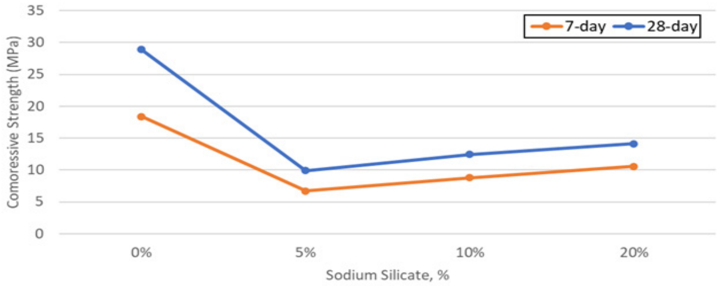

FIGURE 5. Compressive strength vs Sodium silicate

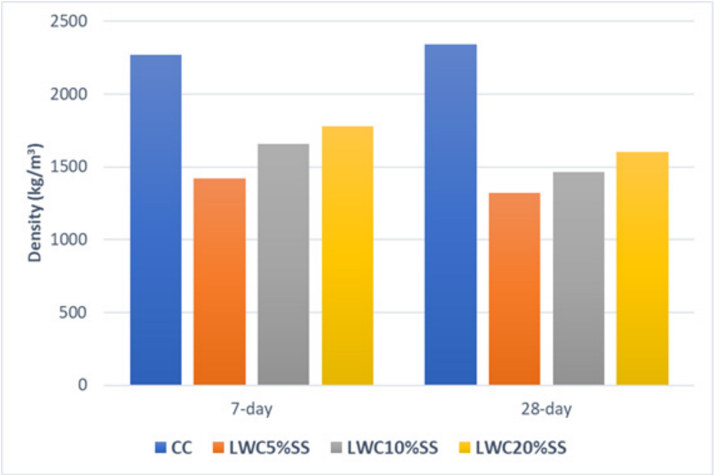

FIGURE 6. Density of concrete

WATER ABSORPTION

Figure 7 shows that CC exhibits a relatively low water absorption rate. Specifically, at the age of 7 days, the water absorption rate is 5.88%, while at the age of 28 days, it decreases to 4.43%. Furthermore, it is worth noting that LWC has a remarkably high rate of water absorption. Specifically, the study found that LWC5%SS demonstrated the highest water absorption rate, reaching 29.2%. When comparing CC and LWC, the absorption rate is a crucial factor due to the utilization of lightweight particles such as LECA balls in lightweight concrete. LECA balls exhibit a low density due to its porous structure, which has air-filled gaps inside the particles. These empty spaces enhance the overall permeability of the aggregate, leading to reduced density. Clay's interconnected porosity enables it to absorb and retain a greater amount of water compared to denser aggregates.

In comparing the percentage of sodium silicate use, the rise in its percentage has resulted in a significant reduction in water absorption, namely 97.3% lower when comparing 20% sodium silicate to 5% sodium silicate. Sodium silicate functions as a water reducing agent by reacting with calcium hydroxide in the cement paste to produce a gel-like material known as calcium silicate hydrate (CSH). Sodium silicate has undergone a chemical reaction with calcium hydroxide generated during the process of cement hydration. This chemical reaction generates extra calcium silicate hydrate (CSH) which enhances the density of the microstructure. A more compact microstructure limits the flow of water through capillary holes, resulting in a decrease in water absorption (Wang et al. 2022). Previous studies have shown that the use of sodium silicate resulted in a 13.3% decrease in water absorption compared to conventional concrete. Additionally, the use of 55% ethyl silicate also led to a reduction in water absorption (Wang et al. 2022).

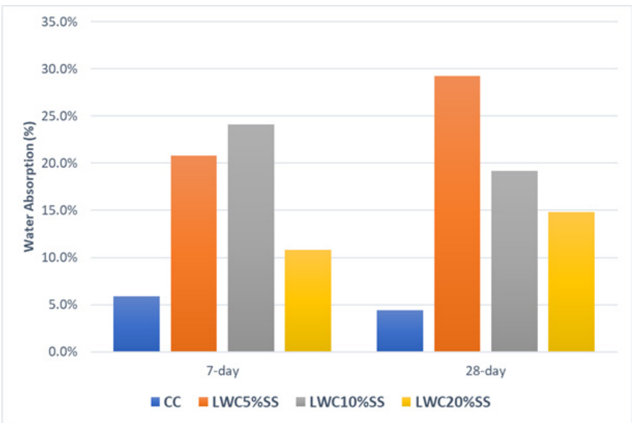

FIGURE 7. Water absorption

CONCLUSION

In conclusion, incorporating sodium silicate into lightweight concrete mixtures to promote the usage of LECA as a substitute for conventional coarse aggregate has led to remarkable advancements in construction applications. Specifically, adding 20% sodium silicate generated a large boost in compressive strength, with a 42.5% increase, while reducing the concrete's slump by 20%, which implies a minor drop in workability but an increase in strength. Additionally, the density of the lightweight concrete was lowered by 46.3% compared to CC, which offers major benefits for projects where weight reduction is crucial, such as high-rise buildings or large-span constructions. The water absorption rate also experienced a significant drop of 97.3%, indicating the better durability and lower permeability when employing 20% sodium silicate as compared to combinations with 5% sodium silicate. This research thoroughly studied the impacts of different sodium silicate percentages in concrete utilising LECA as a coarse aggregate, providing insights into designing lightweight concrete for improved mechanical and durability features. These findings give an effective framework for exploiting lightweight concrete in the Malaysian construction sector, matching with the industry's aim to adopt more sustainable and efficient materials by utilizing LECA and sodium silicate as performance-enhancing agents, this work contributes to a more sustainable building method, minimising environmental impact and expanding the lightweight concrete field for broader applications.

ACKNOWLEDGEMENT

This work was supported by Fundamental Research Grant Scheme (FRGS), Ministry of Higher Education, Malaysia under project FRGS/1/2023/TK01/UKM/02/2

DECLARATION OF COMPETING INTEREST

None.

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