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The Uses of Lightweight Material in Civil Engineering -A Review

Wurood Jassim Al-jboori¹, Madhat Shakir Al-Soud², and Asmaa Mahdi Ali³

^{1,2,3}Civil Engineering Department Collage of Engineering Mustansiriyah University Baghdad Iraq

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ABSTRACT

A lightweight aggregate (LWA) is a group of aggregates with a relative density lower than normal density aggregates (natural sand, gravel, and crushed stone), sometimes referred to as low density aggregate. It is utilized for its reduced weight and exceptional qualities in sound reduction, fire resistance, insulation, and geotechnical applications. LWA, or lightweight aggregate, is a cutting-edge construction material that is employed to decrease the overall weight of tall structures. Despite being lighter, it possesses a strength that is comparable to that of regular concrete. In recent times, there has been a significant surge in the use of lightweight aggregate in the field of building, mostly because of its exceptional performance in seismic situations. In addition, substituting natural aggregate with other industrial by-products and trash enables us to minimize the adverse environmental consequences. Laser wavelength ablation (LWA) has also been employed to address a wide range of geotechnical engineering challenges, including the transformation of soft and unstable soil into a suitable and usable property. Lightweight fillings have a weight that is around 50% less than fills made using typical materials. The load reduction, along with the high internal friction angle of the lightweight aggregate, can decrease vertical and lateral pressures by almost 50%, potentially resulting in less settling. This literature study examines the use of lightweight materials, including LECA, Bonza, and Thermostone, in geotechnical engineering applications. The results demonstrate a significant emphasis on improving slope stability and minimizing stresses on susceptible soils. Nevertheless, several knowledge gaps exist regarding the efficacy of these materials under challenging conditions and when subjected to dynamic loads. A growing inclination towards using these lightweight aggregates is observed because of their advantageous environmental and mechanical properties. Further investigation is needed to examine the extended-term performance and interactions of these materials with different soil types in order to enhance their performance in diverse geotechnical situations.

1. Introduction

Lightweight aggregate (LWA) has a well-established history of quality and performance in the construction sector. Since its inception in the early 1900s, LWA created through the rotary kiln method has been widely applied in various construction applications such as asphalt road surfaces, concrete bridge decks, high-rise buildings, concrete precast and pre-stressed elements, concrete masonry, and

geotechnical projects. Naturally occurring materials suitable for producing lightweight mineral granules include pumice, perlite, vermiculite, expandable clay, and slate. The superior quality of LWA is a result of a meticulously controlled manufacturing process. In a rotary kiln, carefully selected shale, clay, or slate is burned at temperatures exceeding 2000°F.

* Corresponding author E-mail address: wurood.aljboori@uomustansiriyah.edu.iq
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The LWA material is then refined to specific gradations, resulting in a premium lightweight aggregate that is chemically inactive, long-lasting, resilient, structurally sound, well-insulated, and water-permeable. Additionally, the process of producing expanded clay enables the recycling of non-hazardous waste materials, eliminating the need for landfill disposal and offering environmental benefits along with economic advantages. LWA provides architects and engineers with increased flexibility in addressing challenges related to dead loads, topography, seismic conditions, project timelines, and financial constraints in today's construction market[1].

A lightweight aggregate is a group of aggregates with a relative density lower than normal density aggregates (natural sand, gravel, and crushed stone), sometimes referred to as low density aggregate. Depending on the source and the manufacturing process, lightweight aggregates exhibit significant variations in particle shape and texture. The shape may be cubic, rounded, angular, or irregular. The texture can range from fine pores and relatively smooth skins, to highly irregular surfaces with large exposed pores. Natural raw materials that are suitable for the manufacture of lightweight mineral granules include pumice, perlite, vermiculite, expandable clay, and slate [2].

In recent years, the contribution of industry to the circular economy has become a *significant* concern. Among these, the mining sector is confronted with significant *issues* relating to the management of a huge quantity of generated waste. *It is important* to address a number of interconnected challenges, including waste management and recycling, conservation of scarce natural resources, reduction of energy use, and reduction of greenhouse gas emissions. *The* construction materials industry *consumes between 8 and 12 billion tons of natural aggregates* per year. According to reports, the construction materials sector consumes the most energy and scarce natural resources (rocks, aggregates, and water), *as well as* emitting greenhouse gases [3].

These materials can be categorized into three main groups [3]:

- a) Natural materials including perlite, vermiculite, clay, shale, and slate
- b) Industrial products such as glass
- c) Industrial by-products like fly ash, expanded slag cinder, and bed ash.

The most commonly utilized lightweight aggregates derived from expanded clays

are Leca and Liapor, while those produced from fly ash are referred to as Lytag, among others. The bulk density of these aggregates varies significantly based on the raw materials utilized and the manufacturing process employed.

The rising need for lightweight materials may be attributed to the escalating weight of transportation systems (road, rail, and air) and the machinery and structures employed in industrial applications. This interest was evident in an increased quantity of articles published in 2008 and following years that addressed elements of material selection and system design that are most suitable for reducing weights in relevant applications. Within the field of geotechnical engineering, the advancements in lightweight materials have been effectively implemented in two distinct methodologies. An initial strategy is to use lightweight aggregates in concrete applications to enable the production of lighter weight concrete components, therefore aiding in the development of lightweight concrete or systems. Therefore, it is anticipated that concrete systems should use lightweight particles that possess a very high specific stiffness and compressive strength [4]. The strategy involves using lightweight materials in fill applications to facilitate the development of lightweight fill materials. Therefore, it is crucial that these lightweight aggregates possess a very low specific stiffness, namely less than 1 kg/dm³, to minimize their impact on the bearing capacity of supporting soils. Lightweight aggregates utilized in this scenario are prone to poor bearing strength and significant potential settlement caused by the under-pushing of

these low density aggregates when put on yielding soils. Therefore, the construction of the tallest and biggest lightweight soil fills ever generated significant deformation risks, making it a challenging and costly task [5].

Recently, the use of lightweight materials in geotechnical applications has become a new method to improve ground stability and lower building expenses. The present literature review examines the novel incorporation of these materials in diverse geotechnical solutions, emphasizing their distinct advantages and prospective future advancements.

2. Definition of lightweight treated soil

- a) Lightweight treated soil is a uniform ground material that may be modified in terms of density and strength, unlike natural ground materials.
- b) This building approach has minimal impact on the surrounding marine environment, as its mixture may be specifically formulated to prevent separation underwater.
- c) It is feasible to effectively repurpose soil that has been dredged or dirt from building debris that contains a significant amount of water.
- d) The mixture's ability to resist separation underwater ensures that the necessary quality is maintained.
- e) Its high flowability allows it to be easily moulded into any desired shape using simply pump supply pressure, without the need for compaction. Consequently, a substantial amount of the material may be deposited within a short timeframe.

3. Lightweight fills material:

A lightweight fill refers to any substance used to substitute a denser in situ soil with the purpose of lessening the burden on underlying subgrade soils. There is a growing trend in the utilization of lightweight fillers in several domains. Multiple materials have been utilized; nonetheless, because of their experimental character, there are no established design

A lightweight treated soil is a ground material with a density that falls within the range of 0.6 to 1.5 g/cm³. The process involves the combination of water with dredge dirt or other soil types, together with lightweight elements like bubbles or beads and stabilizing chemicals. The combination has a significant level of fluidity throughout the process of mixing or placing. Nevertheless, after the material has a reaction with the stabilizing agent, it transforms into a stiff substance with strength properties that are comparable to or superior to those of top-notch soil materials. The lightweight treated soil technique is defined by the following characteristics[6]:

principles tailored to each material. Further investigation is necessary to establish precise design principles for each lightweight fill material currently accessible. The choice of a lightweight fill is often determined by a specific understanding of the characteristics of each fill material in the local area. When undertaking a building project that requires a lightweight fill, there are several alternative materials that can be taken into consideration. Nevertheless, design engineers may overlook certain materials as a potential alternative owing to their limited understanding or lack of experience with them[7].

When building on an area with low-quality soils, there are several possible methods[7]:

- a) The soils can be excavated to a depth where more robust soils are encountered and then filled with a granular material.
- b) A tiny quantity of the impoverished soil can be extracted and substituted with a lightweight substance of reduced density, so forming a buoyant platform.
- c) If the main issue is the in situ soils while they are wet, the land can be permanently drained to an appropriate depth.
- d) The construction process may be divided into stages, and the soils may be subjected to surcharging.
- e) Geotextiles can be laid on top of the current vegetation and then covered with a layer of granular material.

f) The region might potentially be connected via a suspended infrastructure.

lightweight material in this paper are summarized and illustrated with a diagram in Figure(1)

There are several lightweight material that used in civil engineering application , the

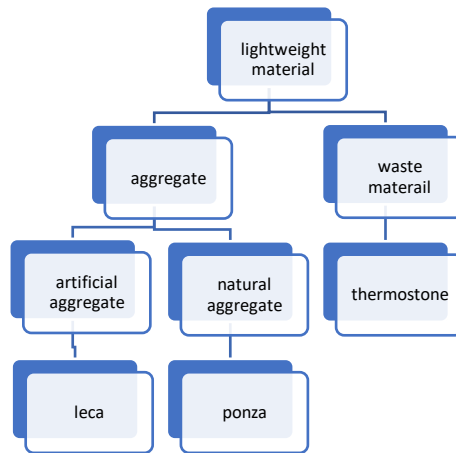


Figure (1) the categorization of lightweight material that used in this paper

3.1 Lightweight aggregates

Lightweight aggregate is utilized for its reduced weight and exceptional qualities in sound reduction, fire resistance, insulation, and geotechnical applications. Lightweight aggregate is utilized in precast concrete for high-rise structures to decrease the load due to its strength and low density. It is employed in concrete blocks to decrease their weight and enhance worker efficiency. Lightweight aggregate systems utilize both naturally existing clays and waste materials as input[8]:

1. Lightweight aggregate (LWA) may be classified into two distinct categories:
 1. These substances exist in nature and may be used directly with mechanical processes such as crushing and sifting.
 2. Those generated from thermal processing of either naturally existing substances or industrial by-products, waste materials, etc. The characteristics of lightweight aggregates (LWA) are connected to the qualities of the aggregates used in their production. This, in turn, relies on the nature of the material and

the method employed to manufacture it. When planning a construction project, the strength and density of the concrete are often taken into account.

3.1.1. Artificial aggregate

Lightweight aggregates are produced using a thermal process that utilizes naturally occurring elements such as clay, shale, slate, perlite, and vermiculite. Contrary to cement, which uses a feed with high calcium content in the rotary kiln, lightweight aggregates are produced from minerals rich in silica that only generate small quantities of CO₂[9].

One of the utmost significant artificial aggregates is **Lightweight Expanded Clay Aggregate (LECA)**

Lightweight aggregate has a proven history of high quality and consistent performance. Since its inception in the early 1900s, lightweight aggregate generated using the rotary kiln technique has been widely utilised in many applications such as asphalt road surfaces, concrete bridge decks, high-rise structures, concrete precast and pre-stressed components,

concrete masonry, and geotechnical projects. The superior quality of LECA is derived from a meticulously regulated production process. Selective clay is subjected to temperatures over 1150° C in a rotating kiln [10].

Expanded clay shale (ECS) and lightweight expanded clay aggregate (LECA) are commonly used lightweight materials that have been effectively employed in geotechnical applications. LECA is referred to as Brazilian lightweight aggregate in Brazil and Azerit in Azerbaijan. LECA is an organic compound that does not include any toxic elements. It exhibits inert behaviour with a pH value that is neutral, possesses resistance to freezing and chemicals, does not degrade in water, is non-biodegradable and non-combustible, and demonstrates exceptional acoustic and thermal insulation capabilities. This material is widely employed in several civil engineering projects because of its lightweight, exceptional strength, and advantageous drainage properties[1].

Currently, this material is widely used in many civil engineering projects, especially in geotechnical applications, because of its lightweight, strong resistance to shear forces, and beneficial drainage properties[11].

LECA has proven to be a highly successful solution for resolving geotechnical engineering challenges and transforming unstable soil into viable land. Lightweight aggregate can decrease the weight of compacted geotechnical fills by up to 1.5 times. LECA has superior thermal resistance compared to soil, sand, or gravel fill, making it ideal for applications that demand thermal stability. It provides long-lasting, cost-effective insulation for water lines, steam lines, and other vessels that are sensitive to temperature changes. This lightweight aggregate is inert, robust, stable, and has excellent drainage properties. It is also ecologically friendly. Additionally, it is easy to handle and offers cost-effective long-term solutions for geotechnical difficulties [11]. Figure (2) shows the Lightweight Expanded Clay Aggregate (LECA) [12]



Figure (2) Lightweight Expanded Clay Aggregates (LECA)[12].

3.1.1.1 Application of Lightweight Expanded Clay Aggregate(leca)

Leca has a wide range of applications in buildings due to its numerous geotechnical uses.

Here is a brief overview of some of these prevalent uses [13]:

a. Minimization of lateral pressure exerted by the soil on retaining walls Figure (3).

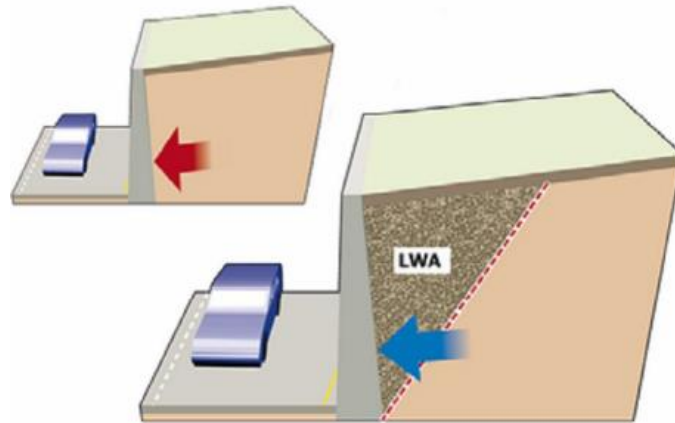


Figure (3) A Schematic Plan of Application of LECA on Reduction of Earth Thrust on Retaining Walls [13].

b. Compensating for the load on soils with poor bearing resistance Figure (4).

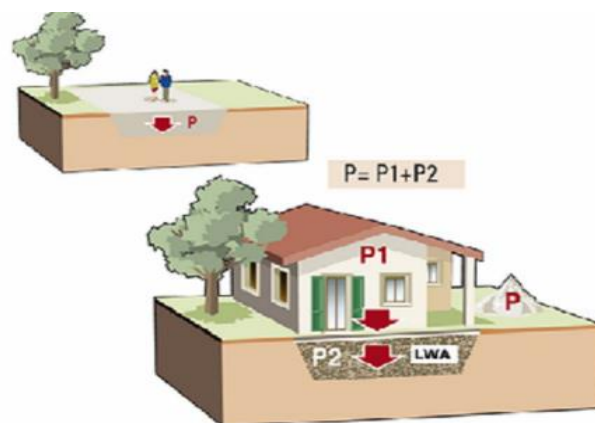


Figure (4) A Schematic Plan of Application of LECA on Load Compensation on Low Bearing Resistance Soils [13].

c. Low-density embankment on inclines Figure (5).

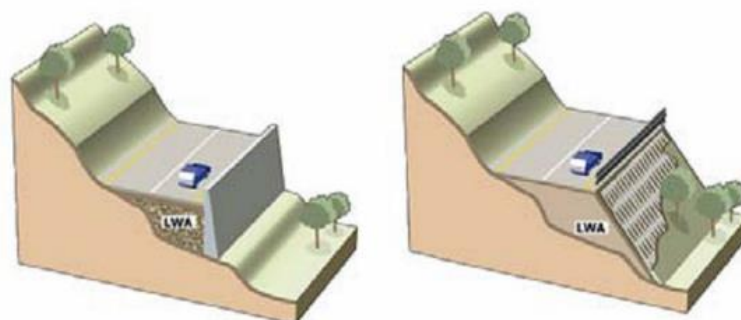


Figure (5) A Schematic Plan of Application of LECA on Lightweight Embankment on Slopes [13].

d. Efficient embankment designed to minimize subsidence Figure (6).

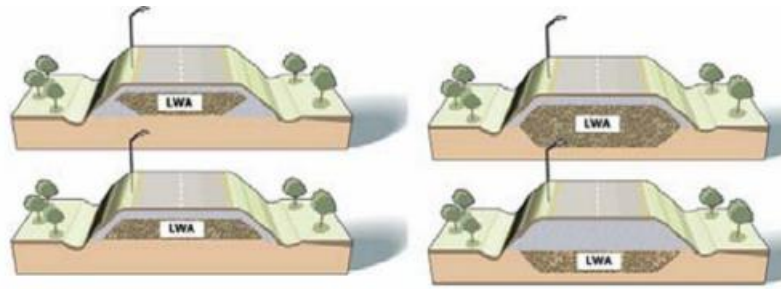


Figure (6) A Schematic Plan of Application of LECA on Lightweight Embankment to Reduce the Settlement [13].

3.1.2 Natural lightweight aggregate:

Most natural LWA are primarily formed by volcanic activity and are therefore limited to specific regions of the planet. Pumice and scoria, which are the most ancient types of lightweight aggregates (LWA), were widely used throughout the Roman era. These materials possess both lightness and strength in their native form, although these characteristics might vary. Pumice is created from the cooling of silica-rich lava that is molten during a volcanic eruption characterised by explosions. Rapid cooling solidifies the substance that is in a molten state. The occurrence of a crystallisation process is impossible. The concept is analogous to that of glass manufacturing, where the material exists in a state that is neither liquid nor solid. It is referred to as a supercooled liquid. The low density of pumice is a result of the entrapment of gas bubbles in the solidified lava during the cooling process. The voids are small and intricately linked. Scoria is a comparable substance, however, with a deeper hue compared to pumice. The shells within it are bigger and have a more uniform shape, and they are not joined together.

Originating from volcanic activity Volcanic lava, upon cooling, becomes a porous and well-sintered substance. Due to a sudden decrease in temperature, the molten mass solidifies. When the molten lava cools rapidly, it does not form crystals and instead becomes glassy in structure, analogous to the creation of obsidian glass. It can be referred to as a supercooled liquid that

lacks a crystalline phase. It exhibits a high degree of amorphousness and possesses a structure like glass. Lava is a molten substance that might potentially include air and gases. When it undergoes cooling, lava solidifies into a porous and spongy mass. Put simply, it creates a substance that is both lightweight and has the ability to absorb and react with other substances. This material is commonly referred to as volcanic aggregate, or alternatively, pumice or scoria aggregate. The aggregates are formed by the mechanical manipulation of lava, namely by means of crushing, screening, and grinding [14]. One of the utmost significant natural lightweight aggregates is (*Ponza*) or (*Pumice*)

Pumice is an extrusive volcanic rock that forms when highly water- and gas-rich lava is expelled from a volcano. Volcanic ash is created when gas bubbles become trapped in solidifying lava [19]. The quick decrease in pressure at the earth's surface results in the escape of gases, which subsequently form many holes after the lava hardens. Due to their high viscosity, acidic lavas are particularly conducive to the development of pumice. Scoria is a kind of crust found on lava flows that resembles pumice. It is denser than pumice stone, resistant to weathering, and typically has a reddish colour. Pumice is highly brittle and readily disintegrates into fine particles. Due to its comparable characteristics and chemical composition to glass, pumice is very abrasive, although far softer than glass. Pumice is the only type of rock that exhibits buoyancy in water, but it will ultimately absorb water and submerge [15].



Figure (7) Different types of pumice stone [15].

Pumice is a formless foam that is created as a result of volcanic explosions. The composition of this substance mostly consists of silica and alumina, with varying proportions depending on the specific geological region of its origin. Additionally, it contains many additional chemical elements, including different oxides and water[16] .

Pumice is a term used to describe a type of volcanic rock that forms when very hot and highly pressurised rock is forcefully expelled from a volcano, resulting in the solidification of foamy lava. The word "pumice" is derived from the Latin word "pumex," which means foam. In the field of business, the term "pumice" refers to bigger stones, whereas "pumicite" refers to small grains or ash. Pumicious materials, which can be either natural or man-made, are finely ground and mixed with lime to create a cement-like substance known as pozzolan. Pumice typically exhibits a variety of pale hues, including white, cream, yellow, brown, dull red, blue, grey, green-brown, or black. Pumice material exhibits a porosity that varies between 40% and 90% and lacks a well-defined crystal structure. Due to the varied nature of pumice studies, more contextual research has been pursued to examine its extraction, physical characteristics, qualities, and practical applications [17],[18].

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3.1.2.1 Pros and cons of pumice or ponza

Pumice offers both benefits and drawbacks when used as a construction material. [20] , some of these are:

- Advantages:
 - a) The transportation cost of aggregate is lower;
 - b) The handling of ready blocks is simpler;
 - c) Constructing with lightweight blocks is more convenient and efficient.
 - d) Mixing concrete manually is more straightforward.
 - e) The transportation of blocks from the production location to the construction site is more cost-effective.
 - f) Pumice blocks exhibit greater resilience.
- Drawbacks:
 - a) Pumice aggregate has lower strength compared to regular aggregate
 - b) Pumice blocks have the ability to soak up water, so it is necessary to apply plaster to the outer walls.

3.2 waste material

3.2.1 Thermostone

Thermostone, also known as autoclaved aerated concrete (AAC), is becoming increasingly important in geotechnical engineering because of its distinctive blend of characteristics. The production of this material involves the combination of fine aggregates, cement, lime, and an expansion agent. This mixture is then subjected to a curing process in an autoclave, resulting in the formation of a structure that is both lightweight and porous. Thermostone possesses notable compressive strength and exceptional thermal and acoustic insulation properties. Thermostone is commonly produced using a mixture of lime, salt, cement, aluminium powder, and water. The primary rationale for including aluminium powder is the nutritive foamy composition of the Thermostone [21].

The lightweight properties of thermostone are advantageous in geotechnical engineering as they help to decrease the burden on soil strata. This is especially important in regions where the soil is weak or unstable [28]. The employment of geosynthetics in retaining walls, embankments, and slope stabilisation serves to mitigate problems associated with soil settlement and pressure, hence improving the stability and longevity of geotechnical constructions[22].

Thermostone is also beneficial in the construction of foundations. The material's insulation reduces frost heave in cold locations, while its capacity to resist water absorption and degradation guarantees long-lasting durability under different weather circumstances[9].

3.2.1.1 Pros and cons of thermostone

There are various advantages associated with the use of thermostone in engineering [23], [24], [25], [26], [27]:

- a) Thermostone has superior thermal and acoustic insulation characteristics, making

it an exceptional option for building purposes

- b) Thermostone may be employed in several building applications, such as reinforced panels, concrete fillers, and partition materials, demonstrating its versatility and adaptability in construction projects
- c) Thermostone demonstrates exceptional fire resistance when covered with plaster, making it a safer choice for structures in the event of fire dangers
- d) The product is characterised by its low weight and ease of handling
- e) Constructing buildings with thermostone blocks can result in substantial energy savings. Houses built with thermostone consume 25% to 30% less electrical energy compared to those made with hollow concrete blocks, leading to cost reductions as well

The drawbacks of using thermostone in engineering are [28], [29], [30], [31]:

- a) Possible fire hazards resulting from variables such as deliberate acts of arson and electrical malfunctions, which might endanger structures built with thermostone
- b) Furthermore, complications that arise during and after the manufacturing process might result in malfunctions in cellular concrete blocks. To guarantee the quality of the product, it is important to meticulously manage the selection of raw materials and monitor production parameters
- c) Noise pollution may be a problem in places where thermostone is used, such as shooting range tunnels. In order to meet acceptable noise regulations, it is necessary to construct soundproofing measures utilising alternative materials, such as hollow concrete blocks
- d) Furthermore, the process of improving thermostone specs by using different additives and substitutes may be intricate, necessitating careful modifications to get the best possible performance and usefulness in construction systems

3.2.1.2. Key attributes of thermostone:

- a) Thermostone is known for its lightweight nature, with a density ranging from 400 to 900 kg/m³. This results in cost-effective construction as it reduces the size of the foundation needed. In comparison to other construction materials, thermostone has a lower density[32].
- b) Thermal and acoustic insulation: Thermal insulation refers to the process of reducing heat transfer between objects or spaces by using materials that have low thermal conductivity. Thermostone has a decent thermal insulation property, with a thermal conductivity coefficient of 0.12-0.14 °C/m. In comparison, clay brick has a coefficient of 0.59 °C/m. This means that a 24 cm thickness of thermostone construction is equivalent to a 36 cm thickness of ordinary brick. As a result, using thermostone can save a third of building materials and labour costs. Additionally, the thermal insulation ability of ordinary bricks reduces energy consumption[33].
- c) Soundproofing Thermostone possesses a notable capacity for sound insulation, meaning it effectively isolates noise and sounds originating from outside the structure. This ability is enhanced due to advancements in civilization and industry. A layer of thermostone that is 24 cm thick provides sound insulation of 48 decibels. This level of insulation is similar to a layer of regular bricks that is 64 cm thick, or a layer of cement cladding that is 77 cm thick on both sides[34], [35].
- d) Introduction to Economics
The use of thermostone, a lightweight material, reduces the stress on foundations compared to other materials like clay bricks, lime bricks, and concrete blocks. This results in cost savings since smaller foundations may be erected for structures[36].

4. Related works:

4.1. Previous Studies of Using Lightweight Materials in Structural Application:

- R. A. Fattah, et al. (2023)[37] demonstrated the utilization of a lightweight fine aggregate, known as "Ponza," obtained by crushing local natural rocks. This aggregate is used to create LWA mortar with varying mix proportions. The objective is to investigate the feasibility of using this mortar to construct blocks that can be installed on the exterior walls of historical buildings, thereby enhancing thermal insulation. Additionally, it includes research on the internal curing ability of the cement mortar formed, which is facilitated by the water absorbed by the surface-saturated dry Ponza aggregate. The procedure involves utilizing three mix proportions (1:1, 1:0.7, and 1:0.5) based on the weight of cement to fine aggregate. The specimens were subjected to curing by being divided into five groups, which consisted of moist curing for durations of 1, 3, 7, and 28 days. The fifth group underwent moist curing for 1 day, followed by the application of a thin coating of flax coat. The dry density, compressive strength, flexural strength, and thermal conductivity were measured at ages 7, 28, and 56 days. The findings indicate that it is possible to produce a lightweight cement mortar with favorable thermal insulation characteristics by adding combinations of 1:0.7 or 1:0.5 cement to LWA (lightweight aggregate), notably Ponza aggregate. The compressive and flexural strengths obtained fell within an acceptable range, measuring around 14.75 and 2.91 MPa, respectively. The bulk density was determined to be below 1,600 kg/mm³, and the thermal conductivity was comparatively lower than that of several other construction materials.
- A. H. Shaalan and A. Z. Hamoodi (2022) [38] examined the mechanical and physical characteristics of lightweight coarse aggregate concrete (LWAC) by using LECA as a lightweight aggregate in combination with steel fibers. The materials and mixtures that are utilized. A total of

thirteen Lightweight Aggregate Concrete (LWAC) mixes were prepared, which included trial mixes specifically designed to examine the impact of the LECA/gravel replacement ratio on both the equilibrium density and compressive strength. To investigate the impact of fiber type and content, we made six more mixtures were made with different steel fiber percentages (0%, 0.5%, 0.75%, 1%, and 1.5%).

- Z. K. Abbas (2022) [39] investigated the efficacy of structural (LWAC) for sustainable building. Lightweight Aggregate Concrete, is employed to decrease the gravitational force exerted by tall structures. It enhances sustainability by reducing the overall expenses of large-scale construction projects, such as high-rise buildings and bridges. LWAC mitigates the detrimental environmental effects by substituting natural aggregate with industrial by-products and trash. (LWAC) possesses a strength comparable to that of conventional weight concrete. it decreased dead load resulting from low density and increased building rates and handling expenses.
- M. A. Gawad and N. M. Fawzi (2021) [40] examined the mechanical characteristics of reactive powder concrete (RPC) that is internally cured using thermostone material. The researchers utilized thermostone aggregate to partially substitute sand in RPC. Various curing techniques, including water curing, air curing, and a combination of water and air curing, were investigated. Optimal partial substitution of 5% thermostone aggregate. Improvements were seen in the compressive strength, flexural resistance (modulus of rupture), and density of the concrete. The greatest augmentation in compressive strength (10.07%) was seen when 5% of the material was partially substituted after 90days. When the specimens are cured for a period of 90 days, there is a 4.53% increase in the modulus of rupture. Additionally, when the percentage of replacement concrete is equal to or greater than 10%, the density of reactive powder concrete decreases. At a replacement percentage of 15%, the concrete exhibits lower density compared to the reference specimen, but it is still higher than the reference specimen. By replacing 5% of the sand with water, the density of internally cured concrete made with reactive powder concrete may be increased by 0.86%.
- M. M. Jomaa'h, et al. (2019) [41] examined the characteristics of concrete by substituting the traditional coarse aggregate in the concrete mixture with two different forms of lightweight material: Expanded Perlite Aggregate (EPA) and Volcanic Pumice (VP). The study examines the differences between ordinary cement concrete and lightweight concrete that contains varying concentrations of aggregates and admixtures. Coarse aggregate was combined with Expanded Clay Aggregates (ECA) in different proportions (0%,25%,50%,75%, and100%). Silica fumes, at a concentration of 10%, and Poly Vinyl Alcohol (PVA), at a concentration of 1.6%, were employed as consistent substitutes for cement and water, respectively. The study demonstrates that the mechanical characteristics of the concrete declined with an increase in the amount of lightweight coarse aggregate. The compressive strength results varied between 10.66 MPa and 28.99 MPa, in comparison to a reference mixture with a strength of 38.44 MPa. The rupture modulus was also measured. The rupture modulus exhibited similar patterns, varying between 1.122 MPa and 3.372 MPa
- S. A. Almawla et al. (2019) [42] examined the characteristics of self-compacting lightweight concrete (SCLC) using natural lightweight coarse aggregate (Ponza). The objective of the study is to assess the physical and mechanical characteristics of

SCLC (Self-Compacting Lightweight Concrete) when the natural aggregate is partially or completely replaced with Ponza, with replacement levels ranging from 0% to 100%. The researchers substituted natural aggregates with Ponza in SCLC combinations. They conducted an investigation to assess the feasibility and simplicity of pouring. Assessed the strength, durability, and other mechanical properties. The study offers valuable insights into the impact of substituting natural aggregates with Ponza on the characteristics of SCLC. The report provides thorough information on the specific outcomes pertaining to the fresh and mechanical characteristics.

- M. Rashad (2018) [43] demonstrated that the addition of LECA to concrete mixes resulted in the following effects: improved workability, reduced density, lower chloride penetration, increased water absorption, reduced shrinkage, decreased susceptibility to freeze/thaw damage, enhanced resistance to segregation, better fire resistance, and improved thermal insulation. The mechanical properties of lightweight concrete are influenced by the type of lightweight aggregate used. However, the inclusion of LECA in the concrete matrix resulted in a loss in mechanical strength. Based on this analysis, LECA can be effectively utilized in both traditional cement-based materials and geopolymers to create lightweight matrices.
- Various specimens of pumice material, as well as cement sand pumice blocks in varying proportions, have been meticulously fabricated and subjected to rigorous testing inside a controlled laboratory environment by Hieronimi A. Mboya et al. (2011) [20] The evaluated pumice material was determined to be classified as well-graded gravel. The material had a maximum dry density of 663 kg/m^3 when it reached its optimal moisture content of 53%. The

pumice block had a compressive strength of 4.8 N/mm^2 , whereas the cement sand block had a compressive strength of 4.7 N/mm^2 . Pumice materials are more ecologically benign than burned blocks due to their extraction and production techniques. Burnt blocks contribute to environmental damage through deforestation for wood fires. Pumice blocks are more advantageous than cement sand blocks, as they are less costly and less prone to erosion when collected from rivers. Pumice blocks are proposed as an alternative to cement sand blocks and charred bricks.

- J. Gao, et al. (1997)[44] observed that the compressive strength of high-strength lightweight concrete was slightly enhanced with the presence of steel fiber. However, flexural strength and splitting tensile were largely improved. It was concluded that the modulus of elasticity of steel fiber-reinforced, high-strength, lightweight concrete was lower than that of steel fiber reinforced normal concrete.

4.2 Previous Study of Using Lightweight Materials in Geotechnical Application:

- A. Zukri (2019) [45] explored the application of Lightweight Expanded Clay Aggregate (LECA) as an alternative material in stone columns for the purpose of stabilising soft clay soils. The researcher employed three-dimensional finite element (FE) analysis and physical modelling to assess the effectiveness of LECA columns and rafts. Increasing the thickness of the LECA layer has been proven to have a substantial impact on reducing settling. Deeper replacements can see gains of up to 80%. They created five design charts to forecast settlement and bearing capacity, which were verified using both numerical and physical modelling.
- M. S. Bajestani et al. (2018) [46] employed direct shear Test to determined the shear

strength of LECA at various degrees of normal stress. The study also used triaxial testing to assess the shear behaviour of LECA. LECA has a high frictional angle and a moderate resistance to cohesion, despite their granular form. These materials are very suitable for geotechnical applications, particularly for use as backfills behind retaining walls. The presence of appropriate characteristics, in addition to the naturally reduced bulk unit weight, can significantly decrease the active lateral forces exerted on retaining walls. Moreover, the exceptional energy absorption and optimal rigidity of these materials make them ideal for seismic applications, thereby expanding their potential uses.

- Ö. Çimen et al. (2015)[47] examined the use of Isparta-Karakaya pumice debris to stabilize the high-plasticity clayey subgrade of road pavements. The study investigated the use of leftover pumice for the purpose of stabilizing the clayey subgrade. The physical and index qualities of both clay and pumice were measured. The Pumice was combined with high-plasticity clay at various weight ratios, including 10%, 20%, 30%, 40%, and 50%. Standard Proctor compaction tests were conducted to examine the impact of adding pumice to mixes of clay. The results showed that the addition of pumice enhanced compaction and decreased the possibility for swelling. The Unconfined compression testing and California bearing ratio (CBR) tests demonstrated enhanced mechanical characteristics. The figure (8) below shows the effect pumice ratio at the mixtures. S. B. Reddy and A. M. Krishna (2015) [48] showed that the model walls filled with Sand-Tire Chips (STC) mixes exhibited a substantial decrease in wall deformations and ground pressures. It can be inferred that the use of tire chips in the retaining wall backfill successfully decreases displacements and earth pressures by approximately 50–60%. This leads to a reduction in the size of the wall under
- H. Gao et al. (2011) [49] examined the impacts of integrating Expanded Polystyrene (EPS) into various soil compositions. Expanded polystyrene (EPS), renowned for its low density and impressive strength-to-density ratio, serves as a lightweight geosynthetic material in embankments and retaining structures. Applications including retaining walls, tunnels, and foundations use EPS materials like beads and blocks for thermal insulation, compressible inclusions, vibration dampening, and as lightweight fillers. Geotechnical applications frequently use EPS Geofoam due to its low density, low permeability, and unique mechanical properties. Scientists have examined many characteristics of lightweight geomaterials made from EPS beads, such as unit weight, strength parameters, permeability, water absorbency, deformation, and creep capabilities. The EPS composite soil has the potential to improve slope stability, decrease lateral earth pressure, and provide effective heat insulation in building construction. Additional research can investigate the subject's mechanical properties and real-world applications.

- M. Saltan et al. (2011)[8] examined the utilization of pumice debris from the Isparta-Gelincik area as a stabilizing agent for problematic clay subgrade in road building. The objective of the study is to investigate the potential of Gelincik pumice waste to improve the engineering characteristics of clayey soil during subgrade construction. An analysis was conducted on the physical qualities of the lightweight aggregate material, specifically pumice waste. The pumice waste and high-plasticity clay were combined in different ratios. The experiments conducted encompassed assessments of freezing stability, solidity, strength, Atterberg limits, California bearing ratio (CBR), and dynamic repeated load triaxial (RLT) testing. The researchers discovered that Gelincik pumice debris can serve as an effective stabilizer for troublesome clayey subgrades in road building. The CBR experiment showed enhanced strength with the use of pumice debris. The liquid limit and plastic index values of the mixture were decreased under the specified conditions by increasing the quantity of pumice. The optimal performance was achieved with mixtures composed of 40% pumice and 60% clayey subgrade. The mixing percentages were evaluated to assess the impact on the bearing capacity and resilience modulus of the stabilized subgrade. The CBR value of the local material is quite low, measuring at 6.78%. Following the stabilization process, the CBR value was found to fall within the specified limits of 10%. Furthermore, a significant enhancement in the resilience modulus of 240–250 MPa was noted. The addition of 40% pumice is more advantageous for stabilizing clayey subgrades compared to removing the clayey subgrade altogether. The utilization of pumice debris for stabilization purposes can yield both economic and environmental advantages. Due to its limited demand in the market, locally sourced pumice has a low commercial value, resulting in low transportation costs.
- H. Cetin et al. (2006)[50] The researchers examined the practicality of utilizing tire-chips combined with cohesive clayey soil as a lightweight material for filling. The researchers performed soil mechanical experiments on tire-chips consisting of pure fine and coarse grains, as well as composites with varying proportions (ranging from 10% to 50%). The purpose was to evaluate the qualities of these materials. The findings suggest that blends comprising of a maximum of 20% large-sized tire-chips and 30% small-sized tire-chips are suitable for surface-level uses, such as constructing highway embankments, bridge abutments, and filling in spaces behind retaining structures. These blends have a combination of low weight, low permeability, and high strength, which makes them well-suited for poor foundation soils that have limited bearing capacity and settling problems. Nevertheless, it is not advisable to utilize them in situations where there is excessive moisture and proper drainage is required. If necessary, they might be mixed with highly permeable substances such as sand and gravel.
- J. P. Dugan Jr (1993) [51] examined the use of lightweight fill to tackle settlement and stability issues encountered in the construction of highways and bridges over deep deposits of soft clay. The study discovered that by decreasing the pressures exerted on the clay layer and utilizing the greater shear strength of lightweight fill in comparison to earth fill, this method effectively resolved the problem of embankment stability. Lightweight fill was utilized in the approach embankments for the construction of a new bridge. The objective was to minimize the effects of the nearby preexisting bridge.

- Scrap tires that have been chopped into chips by D. N. Humphrey et al. (1993)[52] provide notable benefits when used as lightweight fill and backfill for retaining walls. An analysis was conducted to examine the engineering characteristics of tire chips, encompassing factors such as particle size distribution, density, compactness, resistance to shear forces, compressibility, and the coefficient measuring the pressure exerted by the tire chips on the surrounding soil when at rest. Notable discoveries include Structure: Tire chips are composed of equally graded particles that are the size of gravel and have a low water absorption capacity. Their compacted density is roughly one-third of that of compacted soils, ranging from 0.618 to 0.642 Mg/cu m, or 38.6 to 40.1 pcf. Shear strength refers to the ability of a material to resist forces that cause it to slide or deform along a plane parallel to its surface. The measured friction angle varied from 19 to 25 degrees, while the cohesion intercept fluctuated between 8 and 11 kPa (160 to 240 psf). Compressibility: Tire chips have strong initial compressibility, which decreases with consecutive unloading and reloading cycles. The coefficient of lateral ground pressure at rest varies depending on the composition of the tire chips.
- I. Ahmed and C. W. Lovell (1993)[53], used shredded tires in highway buildings to determined technical, environmental, and economic advantages in specific circumstances. The prominent advantages of utilizing tire chips include decreased fill weight, enhanced stability, diminished settlements, and the capacity to rectify or prevent slope slips. Additionally, tire chips contribute to reduced backfill strain on retaining structures. Tire chips function effectively as a drainage medium, effectively avoiding the buildup of pore pressures when fills are loaded. They can replace traditional permeable materials for subdrainage, offering separation to prevent the mixing of underlying weak or problematic soils with subgrade and base materials. Additionally, they promote energy and natural resource conservation and make use of significant amounts of local scrap tires, resulting in a positive environmental impact.
- T. M. Allen and A. P. Kilian (1993) [54] The authors explore a different method for constructing earth fill embankments. Wood fiber was utilized to mitigate stability issues, optimize driving pressures, improve stability, and minimize fill settling. In addition, five layers of geotextile were used to minimize horizontal spreading and improve stability. The geotextile layers were placed at a depth of 2.1 meters from the bottom of the fill.
- R. D. Stoll and T. A. Holm (1985) [55] Expanded shale lightweight aggregates weigh approximately half as much as their naturally occurring equivalents. These materials are valuable replacements for regular fill materials where there is a need for a mix of low weight and significant shear strength. As a result of their evenly distributed network of pores, the aggregates demonstrate improved internal stability. The pores, which vary in size from around 5 to 300 μm , are formed inside a consistent and durable vitreous phase. Moisture quickly saturates the pores near the surface with water. ESCS geotechnical fills exhibit superior resistance to liquefaction during seismic events compared to other types of fills. We attribute this benefit to their ability to withstand substantial shear loads and reduce pore water pressure through drainage. To summarize, expanded shale lightweight fill offers a combination of weight reduction, stability, and seismic resilience for geotechnical purposes.

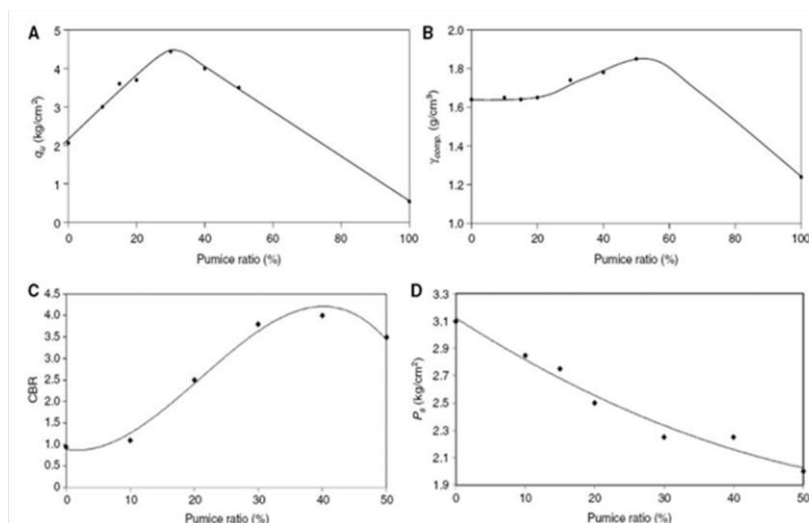


Figure (8) Effect of pumice ratio at the mixtures [47].
 (a) q_u , unconfined compressive strength. (b) γ_{comp} , compacted unit weight.
 (c) CBR. (d) P_s , swelling pressure

5. Conclusion

The use of various aggregate or waste materials yields significant outcomes in terms of producing sustainable light weight aggregate concrete. The use of various lightweight aggregates will decrease the density of standard concrete. Incorporating the lightweight aggregate into regular concrete substantially decreases the structural dead load. The addition of LECA to concrete mixes resulted in the following effects: improved workability, reduced density, lower chloride penetration, increased water absorption, reduced shrinkage, decreased susceptibility to freeze/thaw damage, enhanced resistance to segregation, better fire resistance, and improved thermal insulation.

When the thermestone aggregate is utilized to partially substitute sand in reactive powder concrete (RPC), an augmentation in compressive strength (10.07%) was seen when 5% of the material was partially substituted after 90 days curing. Lightweight Expanded Clay Aggregate

(LECA), Expanded Polystyrene (EPS) and Sand-Tire Chips (STC) mixes are very suitable materials for geotechnical applications, particularly for use as backfills behind retaining walls. The presence of appropriate characteristics, in addition to the naturally reduced bulk unit weight, can significantly decrease the active lateral forces exerted on retaining walls. The pumice enhanced compaction and decreased the possibility for swelling of the high-plasticity clayey subgrade of road pavements.

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* Corresponding author E-mail address: wrood.aljboori@uomustansiriyah.edu.iq
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