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REVIEW PAPER ON PERLITE AS A REPLACEMENT FOR AGGREGATES IN LIGHTWEIGHT CONCRETE

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ABTRACT

In the realm of modern construction practices, the demand for innovative materials capable of meeting structural requirements while mitigating the inherent limitations of traditional building materials has been escalating. Concrete, a quintessential component in construction, has undergone extensive adaptations to address these challenges. One significant area of development is lightweight concrete, which presents an alternative to conventional concrete due to its reduced density and enhanced structural efficiency. The necessity for lightweight concrete arises from various factors, including the need to alleviate excessive structural dead loads, enhance seismic resistance, and expedite construction processes. However, while artificial lightweight aggregates have historically dominated this field, escalating production costs and environmental concerns have spurred a reinvigorated interest in natural alternatives, particularly perlite. This research endeavours to delve into the realm of perlite-based lightweight concrete, seeking to optimize its mechanical strength, durability, and structural performance for widespread application in the construction industry.

Keyword - Low density concrete, Perlite aggregate, Self –weight reduction, Compressive strength analysis, Tensile strength analysis

1. INTRODUCTION

According to ACI, light weight concrete is sometimes referred to as light density concrete. It is characterised as concrete that contains normal weight fine aggregate, light weight coarse aggregate, and potentially some light weight fine aggregate. The density of this concrete is less than 1950 kg/m3. This aggregate's characteristics include low strength, high porosity, tiny apparent density, and increased water absorption. Generally speaking, structural lightweight aggregates are A key component in the building sector, concrete is renowned for its strength, adaptability, and durability. Concrete in its traditional form, however, can be hefty, which can be problematic in some applications where weight reduction is essential.

Lightweight concrete has developed and gained popularity as a result of the drawbacks of conventional concrete. Compared to traditional concrete, lightweight concrete has many benefits that make it a desirable option for a range of construction applications (Chen H. et.al., 2010). Gaining an understanding of the concept and properties of lightweight concrete is essential before exploring its history and importance. The decreased density of lightweight concrete, which is accomplished by adding lightweight aggregates to the mixture, makes it stand out. These aggregates include porous or cellular structures that help reduce the overall density of concrete while preserving adequate structural qualities. They are frequently made of expanded clay, shale, slate, or lightweight natural minerals like perlite and vermiculite.

2. LITERATURE SURVEY & BACKGROUND

Reduced weight, better thermal insulation, and increased fire resistance are just a few benefits of lightweight concrete, a flexible building material. An summary of the major discoveries and research articles that further our knowledge of lightweight concrete is given in this portion of the literature study. Young, J. F., and Mindess, S. (2009). lightweight concrete with aggregates. CRC Publishing. Mindess and Young's book "Lightweight Aggregate Concrete" offers a thorough explanation of lightweight concrete. It discusses a number of topics, such as the structural behaviour of lightweight concrete, mix design issues, and the qualities and traits of lightweight aggregates. The book is an excellent source of information for learning about lightweight concrete in general.

F. De Larrard. (2005). Proportioning Concrete Mixtures: A Scientific Method. Francis and Taylor. De Larrard's book "Concrete Mixture Proportioning: A Scientific Approach" explores the science underlying the proportioning of concrete mixtures, especially lightweight concrete. The book offers a methodical approach to mix design that takes into account variables including admixtures, water-to-cement ratio, and aggregate grading. The fine-tuning of mixture proportions necessary to achieve the desired qualities in lightweight concrete is clarified by this work. In its book "Guide for Structural Lightweight-Aggregate Concrete (ACI 213R-14)," Committee 213 of the American Concrete Institute (ACI) provides thorough guidance for the design and use of structural lightweight-aggregate concrete. Shukla, A. K., and Patel, D. H. (2020). Experimental Study of Lightweight Concrete's Properties Using Various Lightweight Aggregates. Proceedings of Materials Today, 33(2), 707-713. By combining different lightweight aggregates, Patel and Shukla explore the qualities of lightweight concrete in their study work. The effectiveness of lightweight concrete using expanded clay, expanded shale, and pumice aggregates is evaluated through a comparative analysis conducted in this study. It examines important characteristics including density, water absorption, and compressive strength in order to determine if certain lightweight aggregates are suitable for making concrete.

Murat Kurt et al. (2016) conducted a comprehensive empirical investigation to investigate the effects of pumice aggregates, various water-to-(cement + mineral additive) ratios, and the presence of pumice powder on the mechanical and physical properties of self-compacting lightweight aggregate concrete. Pumice is a lightweight material utilised in aggregates, according to their thorough literature review. Density, flow capacity, V-funnel duration, L-box evaluations, compressive strength at 7, 28, 90, and 180 days, splitting tensile strength at 28 days, dry density, water absorption, thermal conductance, and ultrasonic pulse velocity assessments were among the basic characteristics of self-compacting lightweight concrete with pumice aggregates that were covered in the study. They meticulously constructed 24 sets of concrete samples in order to achieve these goals, then divided them into two groups.

Hasan Oktay et al. (2015) conducted a thorough investigation on a variety of concrete types that were created with a constant water-to-cement ratio and contained air-entrained admixtures, silica fume (SF), and super plasticiser (SP). They also investigated the impacts of substituting Light Weight Aggregates (LWA) at different volume fractions (10%, 20%, 30%, 40%, and 50%) for conventional aggregates. Examples of LWA include pumice aggregate (PA), Expanded Perlite Aggregate (EPA), and Rubber Aggregate (RA). In all, 102 samples with various material compositions were painstakingly created and put through a rigorous testing process. Based on the experimental results, the study provided equations to establish relationships between the thermophysical parameters of composite samples. According to the results, adding PA, EPA, and RA decreased the bulk density and compressive strength of the material while also improving the composite concretes' insulating properties.

Bhuvaneshwari. According to a study by K et al. (2017), using natural perlite aggregate in structural light weight concrete has the benefit of lowering the structure's dead weight and increasing the strength of regular concrete. This is achieved by partially substituting sand for perlite in the normal concrete mix at percentages of 5%, 10%, 15%, 20%, and 25%. The results indicate that by optimally replacing 10% of the sand with perlite, the compressive strength rose by 1.85%, the split tensile strength increased by 10.46%, and the flexural strength increased by 10.20%.

Dinesh. According to a study by A et al. (2016), lightweight concrete is crucial for lowering density and improving thermal insulation in concrete structure construction. Expanded clay, vermiculite, and perlite aggregates were used in the creation of structural lightweight aggregate concrete. In terms of compressive strength and split tensile strength, they found that replacing 50% of the weight of aggregate with vermiculite and perlite boosts strength as concrete ages and yields early strength.

Ahmed Ziregue et al. (2016) carried out a thorough investigation into the possible development of building materials through the value-adding of industrial byproducts, with a particular emphasis on waste from quarries' calcareous sand and cork panels used for building insulation. Their results demonstrated the enormous impact of cork aggregates on concrete's lightweight characteristics, which in turn greatly improves the material's thermal performance. In comparison to the reference concrete mix, the research findings showed a noteworthy decrease in thermal conductivity, up to 89% with the greatest dose of cork particles. It was noticed that the amount of cork particles added to the concrete mixture varied, and that this gain in thermal characteristics was accompanied by a loss in mechanical strength.

The construction of ecologically friendly lightweight concretes (LWCs) using Ethyl Vinyl Acetate (EVA) waste was investigated by Nattakan Dulsang et al. (2016). The study concentrated on using EVA waste from the footwear industry as a lightweight aggregate in place of traditional aggregates. In order to maintain a constant water-to-cement ratio of 0.45 and an EVA waste-to-sand ratio of 0.50 throughout all compositions, different amounts of EVA waste (3%, 5%, 7%, and 10% by weight of LWC) were added to the mixes. The results of the study showed that when the quantity of EVA waste content increased, the unit weight of LWCs decreased. Additionally, the generated LWCs' water absorption, chemical resistance, and thermal conductivity were all markedly improved and showed similarities to LWCs with other polymer-based additions. According to the study's findings, using EVA waste as a lightweight aggregate showed encouraging potential for use in LWCs.

Because brick chips are lightweight and porous, Abul Bashar Emon et al. (2016) carried out a thorough investigation on using them as Light Weight Aggregate (LWA). When compared to traditional standard weight concrete, the resultant concrete, known as Light Weight Aggregate Concrete (LWAC), showed worse mechanical qualities and more brittleness. Since brick chips are widely available and reasonably priced in the nation, improving the qualities of LWAC using brick chips was rather important. The study thoroughly examined ways to increase the ductility and strength of concrete by adding brick chips as a coarse aggregate. By replacing conventional steel fibres with inexpensive, locally produced mild steel wire fibre that has been lightly galvanised, it presented a fresh technique. This substitute was suggested since steel fibres are not readily available in local marketplaces in a number of the region's nations, including Bangladesh, where importing them is quite costly. Test cylinders' compressive and splitting tensile strengths were examined, and test beams with different fibre compositions' load-deflection patterns and cracking properties were also assessed. Brick chips, which are widely accessible and financially viable for use in building applications in the area, were used in the study to investigate ways to improve the mechanical qualities and ductility of concrete.

A study by Kim Hung Mo et al. (2016) examined the basic uses of lightweight concrete (LWC), which attracted a lot of attention because of its benefits in terms of cost-effectiveness and design flexibility. However, a possible barrier to the widespread use of LWC in the construction sector was the paucity of thorough knowledge about structural performance, particularly bond characteristics. Structural flaws in reinforced concrete components might result from inadequate reinforcement-concrete bonding.

A thorough investigation of the novel characteristics of Self-Compacting Lightweight Aggregate Concrete (SCLC) made with cold-bonded Fly Ash (FA) and Light Weight Aggregate (LWA) was carried out by Erhan Guneyisi et al. (2016) over a wide range of water-to-binder (w/b) ratios. Three different concrete series with 18 SCLCs that were created with w/b ratios of 0.25, 0.37, and 0.50, respectively, were included in the study. Six distinct combinations were created for each series, taking into account three degrees of nano silica (nS) replacement (0%, 2.5%, and 5.0%) as well as two varieties of coarse LWAs (surface treated or untreated).

Using the water absorption and desorption qualities of ceramsite, Tao Ji et al. (2015) investigated the use of Light Weight Aggregate (LWA) to promote internal curing in Light Weight Aggregate Concrete (LWAC). The early-age autogenous shrinking behaviour of LWAC was considerably impacted by the addition of ceramsite. In order to maintain a constant total water-to-cement ratio (TWC), the study methodically examined the early-age autogenous shrinkage of LWAC with respect to different presetting degrees of LWA. The results of the study demonstrated how using 24-hour pre-wetted ceramsite may reduce the early-age shrinkage of LWAC, which is especially evident during the liquid and skeleton-formational phases. LWACs showed very little expansion strain throughout the hardening period. As a result, while keeping the TWC constant, it was shown that the early-age shrinkage of LWAC decreased as the pre-wetting degree of ceramsite rose.

Using macro-encapsulated Light Weight Aggregate (LWA), Shazim Ali Memon et al. (2015) investigated the development of structural concrete with the potential to control interior temperature. In order to regulate the thermal performance of Light Weight Aggregate Concrete (LWAC) including macro-encapsulated Paraffin-LWA, the study included both indoor and outdoor experiments. The compressive strength and shrinkage strain of LWAC combined with macro-encapsulated LWA were evaluated. The results showed that by successfully lowering indoor temperatures, LWAC combined with macro-encapsulated Paraffin-LWA had a noteworthy role in lowering energy usage. As demonstrated by the interior thermal performance testing, this integration also assisted in dispersing loads away from peak times and stabilising indoor temperature swings.

The compressive strength of mixed oil palm shell lightweight concrete was investigated by Khairunisa Muthusamy et al. (2015) while taking into account different ash replacement levels, including the water-cement ratio, superplasticizer, sand, and cement content. In the early phases of research, cubes (100x100x100 mm) with varying ash replacement amounts were created for testing, and their compressive strength was evaluated. Additional experimental work was carried out once it was determined which 20% replacement levels of Palm Oil Fuel Ash (POFA) had the maximum compressive strength. This next stage used two distinct mix types to investigate the effects of water content, superplasticizer %, sand content, and cement quantity. As reference specimens for the investigation, cubes of oil palm shell lightweight aggregate concrete with 0% POFA and oil palm shell lightweight aggregate concrete with 20% POFA (palm oil fuel ash) were prepared.

In their 2016 study, Muhammad Aslam et al. examined the economic and practical benefits of using industrial waste as building material for ecologically friendly constructions. A solid waste product from the palm oil industry, oil palm shells (OPS), were successfully used to create lightweight, high-strength concrete. But this kind of concrete is especially vulnerable to unfavourable curing conditions. The study described the utilisation of waste materials from the palm oil industry to create cleaner and more ecologically friendly concrete. Oil Palm-Boiler Clinker (OPBC) aggregates, which range from 0% to 50% in OPS lightweight aggregate concrete, were used to moderately replace OPS aggregates

In a research on cellular lightweight concrete (CLC) in masonry, Mohammad Abdur Rasheed et al. (2015) noted that CLC is becoming more and more popular because of its low heat conductivity, density, sustainability, and decreased need for mortar joints. In order to outperform aerated autoclaved concrete blocks, high-performance fiber-reinforced cellular concrete was investigated as a possible substitute for structural purposes in masonry.

Research by Kim et al. (2012) highlighted the efficiency of metakaolin, a popular additive that is known to improve concrete's durability and compressive strength. The relationship between metakaolin and aggregates, however, has not received much attention. In response, they used a variety of fine aggregate types that were on the market at the time to test the effects of metakaolin on lightweight concrete. They used three different kinds of fine aggregates: one kind of simulated expanded shale, two kinds of bottom ash, which is a byproduct of power plants. Each fine aggregate was mixed with metakaolin at several weight percentages of cement replacement (0%, 5%, 10%, 15%, and 20%).

It's noteworthy to note that when heat treated, vermiculite may expand up to 30 times (Neville, 2003) and perlite up to 20 times (Asik, 2006) of its uncalcined volume. As a result, expanded perlite and vermiculite are utilised for insulation because of their extremely low density and strength. Conversely, structural lightweight concrete uses lightweight aggregates with comparatively greater densities, including slate and expanded shale clay. A lightweight aggregate spectrum that displays the unit weight of different lightweight aggregates and the equivalent unit weight of concretes is shown in Figure 2.1.

Lightweight aggregates have a low specific gravity because to their interior cellular or porous structure. These holes, which range in size from 5 to 300 µm, are evenly dispersed in comparatively crackless vitreous material in structural lightweight aggregates. Because surface pores are porous, they may be readily filled in a matter of hours by being exposed to moisture. Pores within are less permeable. It might take months for the internal pores to become saturated. Some internal pores are unconnected, which causes them to stay unsaturated for a long time (Holm & Bremner, 2000).

Güdüz and Ugur (2005) investigated the effects of lightweight concrete (LWC) compositions that included coarse pumice aggregate from Yali Island in the Eastern Mediterranean and fine pumice aggregate from the Nevehir area of Turkey. The concrete produced had densities between 1373 and 1473 kg/m³. The study showed that fine and coarse pumice aggregate mixes may be used to create structural lightweight concrete without the requirement for further admixtures or additives.

The mix design of lightweight aggregate concrete (LWAC) is different from that of regular concrete mix design, as Wang et al. (2005) pointed out in a different study. Because manufactured aggregates are porous, more water is needed to get the necessary workability. For weaker aggregates, the mix design technique usually concentrates on producing a high-strength matrix with a low water-cement (w/c) ratio. The authors came to the conclusion that concrete's workability and compressive strength may be affected by the ratio of fine to coarse aggregate in a mix, which should be between 28% and 42%.

According to Masateru et al. (2007), portlandite is created when glass and calcium-dispersed minerals undergo a pozzolanic reaction. When coupled with calcium in portlandite, hydroxyl particles break down silica particles in the glass to generate a paste known as C-S-H. The cement matrix and aggregate are better bound together as a result of this procedure. A pozzolanic reaction is anticipated to take place on the aggregate surface of fly ash artificial aggregate, which is distinguished by its porous structure and glass content. The parameters of lightweight concrete (LWC) are greatly influenced by the properties of the cement matrix and interfacial aggregate. The authors stressed that improving the strength of regular concrete is not supported by the microstructural arrangement, specifically the point of contact between cement paste and natural aggregate where fractures start. They came to the conclusion that artificial fly ash aggregate adds to the overall strength of the concrete by demonstrating compressive strength that is equivalent to that of natural gravel aggregate.

In contrast to regular concrete (NC), Anwar Hossain (2008) examined the binding properties of plain and deformed reinforcing bars in lightweight volcanic pumice concrete (VPC). VPC's air-dry density after 28 days was found to be 1805 kg/m³. To investigate the impact of concrete type, bond tests were performed on 112 pullout specimens. The load-slip responses, failure modes, and bond strengths of VPC and NC at various ages—from 1 to 28 days—were compared in the study. It was discovered that the distorted bars' binding strength in lightweight VPC was less than that of NC.

According to Shannag (2011), adding mineral admixtures to lightweight concrete (LWC) typically results in an improvement in compressive strength and elastic modulus. The author came to the conclusion that adding micro silica at a rate of 5% to 15% in place of cement while making lightweight aggregate concrete (LWAC) can boost the material's compressive strength by about 57% and its elastic modulus by about 14%. But in comparable mixtures, replacing 10% of the cement with fly ash can reduce compressive strength by around 18% while keeping elastic modulus values same.

Oil Palm Shell (OPS) concrete's modulus of elasticity and stress-strain behaviour were investigated by Shafigh et al. (2012a), who also compared it to Normal Weight Concrete (NWC) and expanded clay Lightweight Concrete (LWC). Four different concrete compositions used crushed large OPS as coarse aggregate. In contrast to many forms of structural lightweight concrete, the stress-strain curve of OPS concrete demonstrated its ductility. At around 18.4 GPa, the study's modulus of elasticity (E) value was the greatest, much exceeding that of earlier studies. According to previous research, the E value of crushed OPS LWC was about double that of uncrushed OPS concrete, at roughly 53% of the control

NWC.

The viability of using granulated foam glass (GFG) in place of natural aggregates in the manufacturing of concrete was investigated by Limbachiya et al. (2012). GFG aggregates showed promise as Lightweight Aggregates (LWA) in concrete after being made from mixed-color glass bottle trash. The study determined how much natural aggregates might be substituted with coarse/fine GFG content (by volume). Concrete's cube and cylinder strengths were little affected by up to 30% coarse or 5% fine GFG, according to compressive strength tests.
The bond strength of lightweight concrete (LWC) made with steel fibres and cold-bonded artificial aggregates was examined by Guneyisi et al. (2013). According to their research, reducing the percentage of artificial aggregates from 60% to 45% improves the cohesiveness of steel and concrete, leading to higher bond strength values.

The characteristics of pressed lightweight concrete (LWC) with calcined diatomite aggregate were investigated by Posi et al. (2013a). After being crushed and divided into fine, medium, and coarse aggregates, diatomite was calcined for four hours at temperatures between 400 and 1000 °C. The pressed lightweight aggregate had a density of 1000–1200 kg/m³ and a 28-day compressive strength of 7.8–12.9 MPa. In comparison to those with uncalcined diatomite aggregate, calcining the coarse diatomite aggregate at 1000 °C and the fine diatomite aggregate at 600 °C enhanced compressive strength, decreased density, and decreased thermal conductivity.

Thomas and Harilal (2014) looked at the effects of cold-bonded artificial aggregates made of cement, fly ash, and quarry dust on the characteristics of concrete. The authors came to the conclusion that cold-bonded artificial aggregates derived from quarry dust might be used successfully in the creation of lightweight concrete (LWC) with the right mix design modifications, offering an alternate way to deal with disposal concerns.

Gomathi and Sivakumar (2015) created artificial aggregates for concrete that were sintered and cold-bonded. The authors noted that artificial aggregates' impact and crushing strengths were judged appropriate for structural uses. Concrete strength increased at a greater cement concentration of 430.3 kg/m³, but decreased when natural aggregates were replaced more often with artificial aggregates. The maximum compressive and flexural strengths, 39.97 MPa and 4.07 MPa, respectively, were found in concrete mixtures that included artificial aggregates 33.

Feras et al. (2018) investigated the use of perlite powder to create cold-bonded artificial aggregates and their use in the creation of concrete. The authors came to the conclusion that the qualities of the produced artificial aggregates were much improved by raising the percentage of fly ash that was replaced by perlite powder to 40%. Furthermore, by lowering the energy consumption and emissions linked to the sintering technique, the manufacturing process used in this work has the potential to increase the usefulness of cold-bonded artificial aggregates in the manufacture of concrete.

According to Ranjith and Thenmozhi (2018), adding steel fibres to the concrete production process raises the density of lightweight aggregate concrete (LWAC). However, when more natural gravel aggregate is substituted with sintered artificial aggregate, the mechanical properties of concrete decrease. Additionally, structural efficiency values showed that high-rise building construction benefits from concrete mixes using sintered particles.

3. CONCLUSION

Over the past few decades, a lot of study has been done on the use of perlite in building materials. Perlite is a naturally formed volcanic glass that is light and has lots of holes in it. In the construction business, perlite is often used as a light aggregate in concrete, plaster, and other building materials. Perlite has the ability to be used as a part of building materials, mostly when mixed with concrete, according to a thorough review of previous research. Adding perlite to concrete can have many benefits, such as making it easier to work with, lowering the unit weight, making it more resistant to fire, and insulating against heat and sound. When used in building materials, it can make them less dense, which makes them perfect for uses that need a lot of thermal and acoustic protection. Natural aggregates like sand and rock can be replaced with perlite, which also helps protect natural resources. This can lessen the damage that construction does to the environment and help the construction business become more environmentally friendly.

But it's also important to know that using perlite as an aggregate can change the mechanical qualities of the concrete in a bad way. For example, the compressive strength will go down and the concrete will soak up more water. When perlite is used as a material in concrete, the compressive strength goes down, which is one of the biggest problems. The porous nature of perlite is to blame for this drop in compressive strength. This makes the concrete more likely to crack and break. Even with these problems, the open structure of perlite can make the material less dense and better at blocking heat and sound.

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