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MECHANICAL PROPERTIES OF RECYCLED LIGHTWEIGHT CONCRETE MANUFACTURED USING RECYCLED LIGHTWEIGHT CONCRETE AGGREGATE: A REVIEW

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ABSTRACT
In the construction industry, the use of lightweight aggregate is increasing rapidly due to its benefits of; low total dead load, reduction in overall project cost, good insulation properties and how they perform during earthquakes. This offers a solution towards attaining sustainability and low environmental impact in the construction sector. In the production of lightweight concrete, lightweight aggregates typically used are; forming agents that creates stable bubbles within the concrete, pumice, diatomite, perlite, clay, shale and vermiculite. Over the years, researchers have explored the benefits of recycled aggregates like waste tire rubbers and bottom ash on the performance of lightweight concrete. However, research on recycled lightweight concrete aggregate is limited and less detailed. This study reviews the studies conducted using recycled lightweight concrete aggregate and the finding revealed that; despite the satisfactory performance and waste reduction potential, concrete manufactured using recycled Lightweight concrete aggregate displayed lower performance compared to standard concrete. Therefore, more research is necessary towards improving the performance of recycled lightweight aggregate concrete.

Keywords: Recycled Lightweight Concrete Aggregate, Sustainable development, Lightweight Concrete, Lightweight Aggregate, Construction wastes

INTRODUCTION
Sustainable development is of great importance for various reasons among which most Earth's resources are non-renewable. The construction industries are high consumers of natural resources and massive waste producers (Cachim, 2009). The extraction of raw materials like rocks from which sand, coarse aggregate and cements ingredients are derived from exposes radioactive materials that will be detrimental to humans. Many countries around the globe are suffering from the impact of industrial waste accumulation and building demolition causing health and environmental issues. (Rao et al, 2007). Therefore, one of the efforts towards achieving a sustainable construction is the utilisation of recycled concrete which will significantly reduce the need for virgin aggregates and materials for construction.
Globally, there is a significant increase in natural aggregates utilization due to infrastructure and construction development. This consequently increases the demand for construction aggregates to over 26.8 billion tons (Fedonia, 2007). Construction and demolition waste programmes have been established in various part of the world, specifying laws that restrict waste production in the form of prohibitions and taxes. The major players influencing waste generation include; inadequate contribution of non-regulatory sectors in waste collection, poor implementation of sustainable procurement systems, and lack of sustainable

waste management plan. (Adebayo et al., 2012, Ajayi et al., 2017). Recycled concrete are generally cheaper and easier to obtain compared to virgin aggregate and this fact encourages researches to investigate and improve the performance of concrete made from recycled aggregate. (Nura, 2021 and Achtemichuk et al, 2009).

The adoption of lightweight concrete can be dated back to the Roman times where it gained recognition due to its superior thermal insulation properties and low density (Bashandy et al, 2017). The significant benefits of lightweight concrete include; reduction of overall construction cost, structural steel quantity reduction, dead load reduction, better fire resistance, low thermal conductivity and insulation against sound and heat. (Cavalline et al, 2017; Miller et al 2017). The disadvantages include; more drying shrinkage, porosity, and more care required during placement. Lightweight concrete are generally applied as under beds for roof slabs and floor construction to substantially decrease the dead load. It is also used for insulated sections of walls and slabs. (Topcu, 1997).

The importance of examining lightweight concrete for sustainable construction cannot be over-emphasised. Researchers are constantly investigating the utilisation of waste materials as lightweight aggregate in concrete production. Therefore, the current study aims to present the influence of using lightweight recycled concrete aggregates on the properties of lightweight concrete.

LIGHTWEIGHT AGGREGATE

Aggregate with dry loose density below 1200kg/m3 or particle density lower than 200kg/m3 is defined as lightweight concrete. The encapsulated pores within the structure of the particle of an appropriate lightweight aggregate have to be combined with both the surface vesicles and interstitial voids. Nevertheless, the combination of these features should not increase the density of concrete either by cement paste pervasion into the body of aggregate particles or significant water absorption when aggregate is mixed into concrete. (Kumar et al, 2018)

Lightweight aggregate used for construction can be divided into two categories;

a. Artificial lightweight aggregates which include; expanded clay, foamed slag, blast furnace slag, expanded shale and slate, recycled waste materials e.t.c
b. Naturally occurring aggregates obtained and ready for use after crushing and sieving. Examples include; scoria and pumice aggregates.

LIGHTWEIGHT CONCRETE

Lightweight concrete are manufactured by injecting air into the concrete mixture. This will create stable air bubbles within the concrete leading to reduction in weight and density of concrete. Another method of production is by replacing the virgin aggregates with cellular, hollow, porous, and recycled aggregate (Newman, et al. 2003). Lightweight concrete are categorised as;

a. No-fines concrete: This type of concrete contains only cement and rough aggregates that provides voids within the concrete. It offers advantages of low density, less cost, low thermal transfer, no segregations and capillary rises. (Neville, 1981).
b. Formed concrete: Formed concrete otherwise known as aerated concrete are made by mixing cement, water, sand and little amount of aerated agent. The aerated agents creates bubbles within the concrete which offers benefits of; reducing density, and good thermo-acoustic insulation. However, this concrete has been reported to display high water absorption rates and lower compressive strength. (Arreshvhina, 2002, Kumar et al 2018)

c. Lightweight aggregate concrete: Lightweight concrete typically contain cement, lightweight fine and coarse aggregate, and water. They are widely adopted in construction today and more research has been channelled towards alternative lightweight recycled materials to use as aggregate.

RECYCLED LIGHTWEIGHT CONCRETE AGGREGATE

The advancement in the utilization of lightweight concrete for infrastructural development has triggered the need to investigate the mechanical properties of lightweight concrete manufactured from recycled lightweight concrete aggregate. This is in an effort to address the issues associated with construction and demolition waste. Recycled lightweight aggregate concrete are obtained from crushing waste lightweight concrete. Research and findings on the effect of this type of aggregate on the mechanical properties of lightweight concrete has been very limited.

EFFECT ON COMPRESSIVE AND TENSILE STRENGTH

In 2015, a study was conducted by Borhan to investigate the properties of a lightweight concrete produced using a recycled lightweight concrete aggregate. The researcher utilised crushed cellular concrete as partial replacement for both fine and coarse aggregate at progressively higher percentages. A progressive reduction in strength was recorded as the percentage of lightweight aggregate increases. At 20% and 100% replacement, the strength were 22.40 Mpa and 8.40 Mpa respectively; resulting to 32% and 72% strength reduction. The strength decrease was attributed to the fact that the structure of lightweight concrete contains voids which are produced due to the hydration of cement or interaction of aluminium powder and $Ca(OH)_2$ from lime. The tensile strength decrease followed similar trend to that of the compressive strength. With an increasing replacement ratio (20 and 100%), a reduction of 28% and 73% was recorded respectively. Referencing the issue of parking density associated with using recycled aggregate which affects its mechanical properties, durability and workability in fresh state, Borhan (2015) recommended that conventional mix design methods be improved to attain maximum packing density for recycled concrete.

A recent study recorded a compressive strength decline by 10% and 14% when Crushed cement –sand bricks where incorporated to replace natural aggregate at 25% and 75% respectively. Grade 25 concrete was manufactured and the 28 day compressive strength at 25% replacement was 21.895 Mpa. Beyond 25%, a progressive reduction in strength was recorded and the researchers attributed this behaviour to the low density of cement-sand bricks (2070 kg/m^3). Similarly, finding for the tensile strength followed very similar trend resulting in a 5% and 35% reduction at 25% and 75% replacement respectively. The recorded 28 days tensile strength values are 1.336Mpa and 0.835 Mpa (Ilya et al, 2018)). This results of this study is further validated by the research of (Debied et al, 2008), where similar experiment was conducted using crushed brick aggregate. They concluded that it is possible to produce concrete containing crushed bricks as aggregate with similar properties as standard concrete provided the percentage replacement using recycled aggregate is limited 25% for coarse aggregate and 50% for fine aggregate.

Recycled lightweight aggregate obtained by crushing, screening, grading and drying of lightweight recycled concrete made with waste shale ceramsite was utilised in a study by Li et al, (2021) to investigate its effect of such aggregate on concrete. The lightweight recycled aggregate was incorporated as % replacement for coarse aggregate at 0%, 25%, 50%, 75% and 100% . Findings revealed 29% reduction in compressive strength at 75% replacement and 46% reduction at 100%. Recorded values for the cubic compressive strengths are 37.62Mpa, 31.82Mpa, 27.72Mpa, 26.68Mpa, and 20.57% respectively.

Alaa et al, 2017 reported a compressive strength decline of 53.5% (10.7Mpa) and a total weight reduction of 13% when crushed light bricks were incorporated to replace natural coarse aggregate in the manufacture of lightweight concrete. In an effort to further reduce the weight of the concrete, an additive ADDIPOR-55 was employed at varying percentages (10%, 20%, and 30%). This showed very little effect on the strength leading to a total strength reduction of 50.8% and a weight reduction of 14% compared to the control concrete where dolomite were used as coarse aggregate. After 10% addition of ADDIPOR-55, a progressive decline in strength was evident. The tensile strength reduction was about 42.5% and follows similar trend to the values of compressive strength. Johnson et al, (2014) recommended an optimum replacement percentage of 30% in their study where waste concrete sludge aggregate and fly ash was utilised in the production of lightweight formed concrete.

CONCLUSION

This paper reviews the mechanical properties of recycled lightweight concrete manufactured using recycled lightweight concrete aggregate. The following conclusions are drawn based on the findings from past research.

- Recycled lightweight concrete aggregates have been shown to lower the mechanical properties and performance of recycled lightweight aggregate concrete and concrete in general. Despite this lowered quality, it is significant to reduce the negative environmental impact resulting from disposal of lightweight concrete. Hence, more detailed research is needed where different admixtures and careful alterations are employed towards improving the performance of this type of concrete.
- More research on the influence of lightweight concrete aggregate on concrete properties such as shrinkage, crack formation, CO_2 absorption, fire resistance, acid resistance, and chloride ion resistance are required to have compressive data for further research.

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