LIGHTWEIGHT CONCRETE WITH EXPANDABLE AGGREGATE FOR ARCHITECTURAL APPLICATIONS: A LITERATURE-BASED STUDY

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ABSTRACT

The usage of lightweight concrete has a significant importance in contemporary architecture dues to its ability to reduce structural load, higher thermal performances and unlocks methods to innovative design ideas. Perlite, vermiculite, and expanded clay are examples of expandable aggregates that have been used to create concrete mixtures that are not only lighter but also more environmentally friendly. Reviewing the literature on the use of these materials in lightweight concrete, this paper focuses on their mechanical and physical characteristics, potential for architectural use, and environmental benefits. This study reveals the material benefits and sustainable objectives and performance of the material in architectural uses.

1. INTRODUCTION

Concrete has long stood as one of the most essential materials in the construction industry, shaping the foundation of modern architecture and infrastructure. From ancient Roman structures that have endured for centuries to today's high-rise buildings and bridges, concrete has continuously evolved to meet changing performance and design demands. The strong and durable widely used traditional concrete has other challenges than being heavy like obstacles in achieving sustainability, structural load distribution and transportation. As architectural design develops and moves for innovation the constraints in traditional concrete laid path in search to lighter, energy efficient and environmental friendly materials, in which light weight concrete has become a promising alternative which offers less self-weight, better thermal resistance.

There are more than handful of researchers and researches exploring the methodology of preparing lightweight concrete. The methods includes sing variety of aggregates to achieve ligt weight, durability and strength. Some of them include natural aggregates like pumice and perlite and artificial materials like expandable clay vermiculite, polystyrene beads. Among which expandable clay got its attention due to its property of making air voids in the internal area, which not only reduces the density and self-weight and provides thermal insulation, fire resistance and acoustics. Earlier works by various researchers have examined the balance between density reduction and compressive strength, while more recent studies focus on optimizing mix proportions and surface treatments to enhance bonding within the cement matrix. Collectively, this evolving body of research highlights the expanding role of lightweight, expandable aggregate concrete in sustainable and performance-driven architectural design.

In the current context contemporary architecture is formed in the concept of using building materials that are not just structurally efficient but also sustainable concern and environmentally responsive. Among these practices, lightweight concrete has emerged as a compelling option. Unlike traditional concrete, lightweight concrete uses aggregates that has lower density typically formed through processes that expand natural materials like clay, perlite, or shale. The aggregates used are typically called as expandable or lightweight aggregate. Some examples of light weight concrete are shown in fg.1. The internal pore structures of these reduces the self-weight of concrete. The advantages of reducing the self-weight includes having thinner structural members and also helps to improve total energy performance of the building.

Aim of this paper to synthesize key findings from recent studies to offer insights into the opportunities and challenges associated with this material.

Image source:https://doi.org/10.1007/s44290-024-00015-9

Fg.1 Different types of light weight aggregates.

a. sintered fly ash aggregate , b. pumice , c. expanded clay aggregate , d. poly-propylene fibre , e. cenosphere , f. GIB , g. coconut shell , h. GGBS , i. cinders , j. ceramsite sand , k. diatomite aggregate , l. aluminium powder , m. vermiculite , n. palm ash , o. HDPE , p. PIRW , q. crushed clay bricks , r. EPS , s silica fume , t. palm kernel shells.

2. MATERIAL CHARACTERISTICS OF EXPANDABLE AGGREGATES

Expandable aggregates play a major role in giving lightweight concrete its unique qualities. These materials like expanded clay, perlite, and vermiculite are created by heating natural raw materials at very high temperatures, which makes them expand, almost like popcorn. This process traps air inside the particles and gives them a cellular structure with lots of tiny pores. Because of this, they're much lighter than regular crushed stones or gravel.

Different types of light weight aggregate as shown in Fig.1 used by researchers are listed below:

LECA Lightweight expanded clay aggregates
PA Pumice aggregate

GGBS Ground granulated blast-furnace slag
DA Diatomite aggregate
HDPE High density polyethylene granules
GIB Glazed Iso Ball
EPS Expanded polystyrene
PKS Palm kernel shells
RHA Rice husk aggregates
CS Coconut shell
PET Polyethylene terephthalate
RPA Recycled plastic aggregate
PIRW Polyisocyanurate foam waste TATile aggregate

Each type of expandable aggregate brings its own advantages to a concrete mix. For instance, expanded perlite is known for being extremely lightweight and great at thermal insulation. Though vermiculite provides insulation and fire resistance, to achieve structural stability expandable clay is preferred due to its high compressive strength and durability

The interfacial transition zone (ITZ) is the region of contact between the light weight concrete and the cement paste. The performance of light weight concrete lies in the connection of the aggregate and cement paste in this zone, studies show that concrete becomes weaker in this zone due to natural pores in this zone which can be overcome by pre wetting the aggregates, using right mix proportion and proper curing of concrete. When done correctly this issue can be fixed and strength, durability can be achieved in light weight concrete.

3. DISCUSSION AND RESEARCH

Light weight concrete is not just a concrete wit aggregates it’s a tool for architects to expand their creativity. It gives freedom to designers to open up possibilities to innovate varies shapes, function and sustainability. As the light weight concrete has less density than the traditional concrete it reduces the overall weight of the structure with indeed reduces the load carried to foundation and other structural supporting systems. This is especially helpful in retrofit projects, rooftop extensions, or buildings in earthquake-prone areas, where keeping the structure light is very important.

Other properties of light weight concretes like its thermal insulation make it a environmental friendly material to achieve sustainable design goals. This strategy includes usage of light weight concrete to have better thermal insulation which significantly reduces the need for artificial heating or cooling systems making it a great passive cooling technique. For example, in a warm or hot region using of light weight concrete with aggregates like perlite or vermiculite helps to maintain temperature within the building due to air pores in the concrete that creates thermal insulation.

In aesthetical point of view light weight concrete is very flexile so that it can e molded into varies forms and shapes, give texture and depth details or cast into thin and elegant panels which is difficult to make in traditional concrete. As its self-weight is significantly less it can casted in off-site and assembled quickly in on-site.

In terms of sustainability, light weight concrete satisfies any aspects of modern green building standards. The embodied energy of light weight concrete using expandable concrete is reduced because the raw material requirement for expandable aggregate is less and mostly made out of natural and recycled materials. .According to studies published in journals like Sustainability (MDPI) and the Journal of Building Engineering, buildings that use lightweight concrete panels tend to have lower operational energy consumption, especially in climates where insulation on is crucial. Lower density of the material helps I easy transportation and reduces transportation emission and less stress on construction equipment. If other sustainable materials like fly ash, slag, or silica fume is added to light weight concrete even more carbon footprint can be reduced. This makes it not only efficient but also a smart and eco-friendly choice for sustainable construction on projects.

Though there are lot of studies on light weight concrete, most studies discuss only about laboratory tests and mechanical properties while categories like practical application, long term durability, weather resistance and surface quality gets less attention. Architectural elements such as color stability, moisture behavior, and how the material interacts with other construction materials are also not explored in depth. Also with that, aesthetical experience of lightweight concrete how it looks and feels over time isn't often studied. With today's digital tools like parametric modeling and performance-based simulation, there's a big opportunity to design lightweight concrete mixes that meet not just structural or environmental needs but also creative and aesthetic goals.

4. CONCLUSION

Using expandable aggregates for light weight concrete has significant advantages including the benefits having lower self-weight, flexible to make complex shapes, thermal insulation and aesthetical appearances. Along with these advantages the biggest limitation is the compressive strength with limits the light weight concrete to be used in heavy load carrying structures due to pores which weaker the strength of concrete

Another big limitation of light weight concrete is the some aggregates like vermiculite can e water absorbing and causes shrinking or cracking so requires proper management during mixing. Light weight concrete can also be expensive due to the less availability of light weight aggregates in certain regions. Careful management, material selection, good design detailing, and strong engineering support throughout the project.

Lightweight concrete made with expandable aggregates gives architects a valuable way to combine performance, sustainability, and creativity. Even though it can't replace traditional concrete in high load carrying areas, its benefits such as reduced weight, better insulation, and flexible design options make it a great choice for many architectural applications. This study highlights both the strengths and challenges of using such materials.

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