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PERFORMANCE EVALUATION OF REINFORCED CEMENT CONCRETE USING EXPANDED CLAY AGGREGATE (ECA)

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A B S T R A C T

This paper is an experimental exploration on the use of lightweight concrete with Expanded Clay Aggregate (ECA) in part of the substitution of typical coarse aggregates. The major aim is to assess the structural, thermal and physical performance of the Reinforced cement concrete. The concrete mixes with light weights were made using different proportions of ECA which was then standardly cast, cured and tested. Important parameters like the compressive strength, density and thermal insulation were tested and contrasted with the normal concrete. The findings suggest that inclusion of ECA is a significant way of reducing the density of concrete hence lowering the total dead load of buildings. Though there was a slight decrease in compressive strength, the values were still within the acceptable range in non-load bearing use. Along with that, the ECA concrete exhibited a better thermal and acoustic insulation effect owing to its porous makeup. The paper concludes that lightweight concrete made of ECA is a sustainable and economical alternative to modern construction. It has good environmental properties and performance features that have rendered it a potential material in the future construction practice.

1. INTRODUCTION

Expanded Clay Aggregate (ECA) is a lightweight construction resource which is formed after heating natural clay at high temperature which makes it porous and tough. ECA has created a lot of interest in the construction industry because of its special properties including low density, high strength to weight ratio and good thermal insulation. Lightweight concrete has emerged as a key field of research and development with the growing demand of sustainable and energy-efficient building materials. Conventional concrete, in spite of its popularity, adds a lot of dead load to structures, resulting in an increase in material use and cost of construction. ECA as a partial substitute of traditional aggregates is useful in decreasing the weight of a concrete to a reasonable level without compromising the strength and durability. Further, ECA improves thermal and acoustic performance of concrete, making it applicable in the contemporary building works. This paper is devoted to the production and analysis of lightweight concrete with the help of ECA.. This is to examine the structural behaviour, strength properties and insulation properties of the material. The study gives an insight on the possibility of ECA being an alternative in the construction that is sustainable.

1.1 Background

Concrete is a construction material that has gained popularity all over the world because of its strength, durability, and versatility. Nevertheless, conventional concrete is dense and this makes it heavier in structure and use of materials. To minimize dead load and enhance energy efficiency, there has been the development of lightweight concrete. Expanded Clay Aggregate (ECA) is a lightweight substance which is formed by subjecting natural clay to high temperatures. It also has porous structure and thus can be used to insulate heat and absorb sound.

1.2 Problem Statement

Traditional concrete adds to the large structural loads and energy use. Sustainable materials are required that will help in weight reduction without compromising on performance.

1.3 Objectives

- To investigate the characteristics of lightweight concrete with the help of ECA.
- To measure compressive strength and durability. Applications: To examine thermal and acoustic insulation properties.
- To determine wall panel suitability.

1.4 Scope of Study

This paper is based on Reinforced cement concrete with ECA and their structural and thermal performance is evaluated..

2. LITERATURE REVIEW

The use of lightweight aggregates in concrete has been investigated in the past.
- Rashad (2018): ECA concrete had better insulation properties.
- Vijayalakshmi (2018): Reduced density was reported with the use of ECA.
- Caceres et al. (2019): Investigated the utilization of industrial by-products with lightweight aggregates.

Mulgund and Kulkarni (2018): Experienced decrease in dead load and better economy. Results indicate that lightweight concrete decreases density, but can also decrease compressive strength albeit in a small amount.

3. MATERIALS AND METHODOLOGY

The approach used in this research will include the preparing and testing of lightweight concrete that uses Expanded Clay Aggregate (ECA). These materials are cement, fine aggregate (sand), coarse aggregate, water, and ECA as a partial substitute of traditional aggregates. The desired strength and workability were attained through the standard procedures to come up with the mix design.

First, ECA was moistened in water to be well absorbed and bond with the cement matrix. Concrete mixes were made at varying ratios of ECA and specimens (cubes and prisms) were cast in standard moulds. The samples were pressed, polished and dried in controlled conditions that lasted to 7 and 28 days.

Tests were done to determine the performance of the concrete after curing. These were compressive strength test, density test and monitoring of thermal properties. The performance was compared to conventional concrete to determine the effectiveness of ECA in enhancing performance. The whole process has been done in a manner that is in line with the conventional testing procedures so that they can be accurate and reliable.

3.1 Materials Used

1.Cement (OPC)

Type: Ordinary Portland Cement (OPC) (43 grade)

SI.NO	PHYSICAL PROPERTIES	VALUES
1	Fineness	225–300 m²/kg
2	Standard Consistency	**26% to 33%**.
3	Setting Time	10 hours
5	Strength	43 MPa
6	Specific Gravity	**3.10 to 3.15**
7	Bulk Density	1500–1600 kg/m³

2.Fine Aggregate

There are a number of significant physical characteristics of fine aggregate (usually sand or crushed stone with a size smaller than 4.75 mm) which influence the behaviour of concrete and mortar.

1. Particle Size and Grading

The distribution of particle sizes is referred to as such.
As determined by sieve analysis.
Sand of good grade enhances workability and minimizes the amount of voids.
Bad grading may cause segregation or over-demand of cement.

2. Shape of Particles

May be rounded, angular, flaky or elongated.
Rounded particles → enhanced workability (e.g. river sand).
Angular particles - superior bonding yet reduced workability.

3. Surface Texture

Smooth or rough face.
Coarse surface of cement paste → enhances bonding.
Smooth texture - enhances workability and lowers bond strength.

4. Specific Gravity

The ratio of weight of the aggregate to the weight of an equal volume of water.
Usually between 2.5 and 2.7.
Of use in mix design and density computations.

5. Bulk Density (Unit Weight)

Weight of total weight divided by unit volume.
Relies on compaction and moisture status.
Applied in calculating the weight-volume ratio in batching.

6. Water Absorption and Porosity.

Porosity: Amount of voids in particles.
Water absorption: Quantity of water absorbed by aggregate.
Water-cement ratio and strength is influenced by high absorption.

7. Moisture Content

Quantity of water available in the aggregate.
Types:

- Dry
- Air-dry
- Saturated surface dry (SSD)
- Wet
- Important in precise proportioning of mixes.

8. Bulking of Sand

Gain in volume owing to moisture content.
Greater in fine sand.
Potentially lead to volume batching errors unless remedied.

9. Fineness Modulus (FM)
Usually between 2.0 and 3.5 in the case of fine aggregates.

3.Coarse Aggregate
Coarse aggregate (material that remains on a 4.75 mm sieve, such as gravel or crushed stone) has a significant contribution to concrete strength and concrete durability. It has the following physical properties:

1. Size and Grading
Measures of largest size and particle sizes.
Common sizes: 10 mm, 20 mm, 40 mm.
Grades of aggregates minimize the voids and enhance strength.
Cement requirement is increased by poor grading.

2. Shape of Particles
Forms: round, angular, flaky, long.
Angular → enhancing interlocking and strength.
Flaky and long → undesirable (less strength and workability).

3. Surface Texture
Smooth or rough.
Coarse texture → enhanced cement paste bond.
Smooth texture - better workability and less bond strength.

4. Specific Gravity
Ratio of the total weight to the same volume of water.
Typically between 2.6 and 2.8.
Useful in mix design computations.

5. Bulk Density (Unit Weight)
Mass of one liter of volume (kg/m 3).
Relies on compaction and grading.
Applied in mix proportioning and batching.

6. Water Absorption and Porosity.
Porosity→ holes within particles.
Water absorption -quantity of water taken up.
Durable concrete should be preferred to be lower absorbed.

7. Moisture Content
Water that is on the aggregate surface or in the pores.
Affects water-cement ratio.
Should be taken into account as part of mix design.

8. Voids Content
Interstitial gaps between the particles.
Reduced void content = reduced cement paste required = cost effective.

9. Impact Resistance and Crushing (Strength)
Shows resistance to loads and shocks.
Good aggregates enhance concrete strength.

10. Abrasion Resistance
Wear and surface friction resistance.
Significant with pavements and roads.

11. Soundness
Strength against weathering (wetting-drying, freezing-thawing).
Unsound aggregates can break up with time.

12. Deleterious Materials
Clay, silt, organic matter or soft particles.
These decrease strength and life cycle.

4.Expanded Clay Aggregate (ECA)
Expanded clay aggregate (also known as lightweight expanded clay aggregate or LECA) is an artificial aggregate that is produced by heating clay at elevated temperatures. Its physical characteristics are rather dissimilar to the natural aggregates:

1. Low Density (Lightweight)
Bulk density: 300800 kg/m 3 (far less than normal aggregates).
Makes it suitable in light weight concrete and structural uses.

2. Particle Size and Shape.
Typically round or oval-shaped pellets.
It comes in various sizes such as 4-20 mm.
Even shape enhances workability.

3. Porosity
Very porous internal structure.
Has numerous air spaces.
Low weight and good insulation properties.

4. Water Absorption
Large relative to natural aggregates.
Be able to absorb a lot of water because of porosity.
Usually pre-wet prior to use in concrete.

5. Surface Texture
External surface is rather hard and coarse.
Gives a good bond with cement paste.

6. Specific Gravity
Less than standard aggregates.

Normally falls between 1.0 and 1.8.

7. Strength
Reduced crushing power compared to normal aggregates.
Sufficient to lightweight structural concrete.

8. Thermal Insulation
Good insulating capability because of air spaces.
Applied in roof insulation and lightweight blocks.

9. Sound Insulation
Good acoustic properties.
Assists in damping sound.

10. Fire Resistance
Resistant to fire.
Does not burn or release toxic gases.

11. Durability
Weatherproof, chemical, and frost resistant.
Long service life.

5.Water

The physical properties of water used in construction (particularly in concrete) have a number of significant effects on workability, strength and durability:

1. Color
Should be colorless.
Colored water can be a sign of impurities.

2. Odor
Should be odorless.
Bad smell indicates organic contamination.

3. Taste
Should not have abnormal taste.
Dissolved salts are indicated by salty or bitter taste.

4. Temperature
Influences the rate of hydration and setting time.
Ideal range: 10°C to 25°C.
Higher temperature: Rapid setting; Lower temperature: Slower setting.

5. Turbidity
Shows suspended particles (silt, clay).
Should be low with good-quality water.

6. Density
Approximately 1000 kg/m³ at 4°C.

7. Viscosity
Resistance to flow.
The viscosity is low which facilitates proper mixing and workability.

8. Surface Tension
Influences the wetting capacity and the connection to cement particles.
Lower surface tension improves spreading.

9. pH Value
Should measure about 6-8 (neutral to slightly alkaline).
Concrete strength can be influenced by acidic or highly alkaline water.

10. Total Dissolved Solids (TDS)
Symbolizes the dissolved minerals and salts.
Overload of TDS can damage concrete and reinforcement.

11. Hardness
Brought about by calcium and magnesium salts.
A moderate hardness is fine; extreme hardness can have an impact on setting.

12. Specific Gravity
Approximately 1.0.
To be used in calculations.

13. Electrical Conductivity
The presence of ions (salts).
Strong conductivity = high level of impurity.

3.2 Properties of ECA

1.Lightweight
2.High strength-to-weight ratio
3.Thermal insulation
4.Fire resistance
5.Chemical inertness

3.3 Mix Design

Coarse aggregates were replaced using different proportions of ECA.

3.4 Experimental Procedure

1.Material selection
2.Mix proportioning
3.Casting of specimens
4.Curing

5.Testing (compressive strength, density, thermal properties

4. RESULTS

Experimental findings show that Expanded Clay Aggregate (ECA) use has significant impacts on concrete properties. It was also found that the density of ECA-based concrete was significantly less than that of conventional concrete, which proved its lightweight characteristics. This minimization of density helps to reduce structural dead load; thus it can be used in the contemporary building projects.

The compressive strength tests revealed that the strength of lightweight concrete decreases with increase in ECA content. Nevertheless, the values of strengths obtained were within acceptable ranges of load bearing structures such as beam, column and slab. The workability of the concrete mix, also, was enhanced by the porosity of ECA.

The thermal performance evaluation showed that ECA concrete has better insulation characteristics than conventional concrete. This can be explained by the fact that the air voids in the aggregate structure decrease the heat transfer. On the whole, the findings indicate that ECA-based concrete offers a compromise between strength and weight loss, as well as enhanced thermal efficiency.

4.1 Compressive Strength

The findings of compressive strength results show that the use of Expanded Clay Aggregate (ECA) affects the mechanical properties of concrete, and the strength tends to decrease with the percentage of replacement of the traditional coarse aggregate. This decrease is largely due to the porous and lightweight qualities of ECA particles that have low crushing strength than the natural aggregates. Nevertheless, even with the minor decrease, the measured compressive strength values were still in acceptable limits of structural and non-structural applications especially at moderate replacement levels. The strength values of lower replacement percentages were comparable to those of conventional concrete thus showing that ECA may be successfully used without much reduction in load bearing ability. Results validate the theory that a balance between decreased density and acceptable strength performance can be achieved at an optimum replacement level.

4.2 Density

The concrete density decreased remarkably with an increase in ECA content. The unit weight of the concrete was significantly reduced as compared to conventional concrete because the cellular structure of the expanded clay aggregates was light. This decrease in density also has a direct contribution in reducing the dead loads in structures, which is especially useful in high-rise buildings, long-span structures and precast elements where weight reduction is essential. ECA concrete is also lightweight in nature which is also economically beneficial in terms of smaller sizes of the structural members and lower foundation loads. The findings confirm that ECA can be used as a good material in the production of structural lightweight concrete.

4.3 Thermal Performance

Tests on thermal performance showed significant enhancement of insulation properties of ECA concrete. Pore structure of expanded clay aggregates within the interior serves as a thermal barrier and lowers the thermal conductivity as compared to regular concrete. This improvement in insulation performance helps improve temperature control in buildings, which can help to lower energy use in heating and cooling. The properties render ECA concrete very appropriate in terms of sustainable and energy-efficient construction. The findings also show that further addition of ECA content increases thermal resistance which is beneficial in climates that need better thermal comfort.

4.4 Workability

Fresh concrete mixes containing ECA exhibited better workability. The concrete mixes had improved consistency and handling characteristics as a result of the porous and relatively smooth surface texture of the aggregates. The slump values tended to rise, which means improved flowability and placement properties. This enhances workability making compaction and finishing easier particularly in overcrowded reinforced concrete sections. Nevertheless, with water absorption by ECA, the mix design must be pre-soaked or adjusted with water to ensure consistency and avoid loss of moisture during mixing.

5. DISCUSSION

The experimental findings reveal that the addition of Expanded Clay Aggregate in concrete greatly enhances its capability to be used in lightweight structures. The density decrease that was observed is a significant benefit because it decreases self-weight of structures and thus decreases loads on foundations. This may lead to high savings on construction costs especially in long span and multi-storey buildings.

Whereas compressive strength was gradually decreasing with increase in ECA content, the values obtained were within acceptable structural limits. This means that the ECA concrete can be successfully utilized in load bearing operations besides the added benefit of less weight. The findings correspond with the results of previous literature pointing out the trade-off between strength and density of lightweight concrete systems.

The improved thermal insulation of ECA concrete is mainly attributed to porous interior structure of expanded clay aggregates, which inhibit the movement of heat. This helps to achieve better energy performance and indoor thermal comfort and therefore the material is applicable in sustainable building performance. Moreover, the acoustic insulation qualities of porous aggregates enhance further its usability factors.

Another positive result was the increased workability, which allowed placing and compacting concrete more easily. Some shortcomings were however recognized and specifically, lower strength with increased replacement percentages and optimization of mix proportions to balance mechanical performance and physical performance. Future studies can be aimed to use ECA together with additional cementitious products or fibers to increase the strength without losing the lightweight properties.

6. CONCLUSION

The paper has examined the use of Expanded Clay Aggregate as lightweight coarse aggregate in reinforced cement concrete. The findings corroborated the fact that ECA plays a major role in decreasing the concrete density, and thus the overall structural load and it is applicable in the contemporary lightweight construction industry like in high buildings, bridges, and prefabricated components.

Although a minor decrease in compressive strength was noted, values obtained were sufficient in most structural applications such as beam, slabs and columns. Moreover, ECA concrete had better thermal insulation and possible acoustic advantages, which helped to improve building performance and energy efficiency.

Sustainably, ECA has environmental benefits as it is naturally-found and contributes to resource-efficient building. All in all, lightweight concrete with ECA is a viable, cost-effective and sustainable alternative to regular concrete. Future research can be aimed at how to maximize mix design and enhance strength properties towards larger-scale structural applications.

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