e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:11/November-2024 Impact Factor- 8.187 www.irjmets.com

EXPERIMENTAL STUDY ON LIGHT WEIGHT CONCRETE WALL PANEL USING ECA

Sre Adethya V[*1], Manojkumar G[*2], Manojkumar S[*3], Poomathy M[*4], Tharun S[*5]

[*1]Assistant Professor, Department Of Civil Engineering, Sri Shakthi Institute Of Engineering And Technology, Coimbatore, India.

[*2,3,4,5]Students, Department Of Civil Engineering, Sri Shakthi Institute Of Engineering And Technology, Coimbatore, India.

ABSTRACT

In this Project we are Presenting the ultimate Green Construction Material. Introducing the revolutionary make in Indian Product called Expanded Clay Aggregate (ECA), Expanded Clay Aggregate (ECA) is a unique Green Construction Material. It is 100% Natural and Inert light weight aggregate. Also an Excellent thermal & Sound insulting material. A Construction wall Panel of high Quality is a vital Construction Component to many buildings Professional or Residential Worldwide, since there are an array of options available, most of them are different version of Light weight ECA Solid Precast Concrete Construction wall Panel.

Keywords: Concrete Wall Panel Using ECA, (ECA) Expanded Clay Aggregate, Green Construction Material, Light Weight Concrete Wall Using ECA.

I. INTRODUCTION

The experimental study on lightweight concrete wall panels using Expanded Clay Aggregate (ECA) aims to investigate the performance, strength, and durability characteristics of concrete panels incorporating ECA as a lightweight aggregate. ECA is known for its thermal insulation properties and low density, which can contribute to reducing the overall weight of concrete structures while maintaining adequate strength. The study focuses on evaluating the feasibility of using ECA in wall panels, analyzing key factors such as compressive strength, thermal conductivity, and structural integrity, to assess its potential for sustainable and energy-efficient construction applications.

II. METHODOLOGY

The methodology for the experimental study on lightweight concrete wall panels using Expanded Clay Aggregate (ECA) involves the following steps:

1. **Material Selection**: ECA is selected as the lightweight aggregate, with standard ingredients like cement, fine aggregates, water, and additives.
2. **Mix Design**: Various concrete mixes are designed by varying the proportion of ECA, ensuring consistency in water-cement ratio and air content.
3. **Panel Preparation**: Concrete panels of standard dimensions (e.g., 600mm x 600mm x 100mm) are cast using the designed mix. The panels are cured for a specified period (e.g., 28 days) under controlled conditions.
4. **Testing**: The prepared panels undergo tests to evaluate:

- **Compressive Strength** (using a Universal Testing Machine)
- **Thermal Conductivity** (using a thermal conductivity meter)
- **Water Absorption** and **Density** to assess durability and lightness.
- **Flexural Strength** and **Bond Strength** to measure structural integrity.

5. **Data Analysis**: Results are analyzed to determine the impact of ECA content on the mechanical and thermal properties of the wall panels, comparing them with traditional concrete panels.
6. **Optimization**: The mix with the best performance in terms of strength, insulation, and weight is selected for further applications in construction.

This methodology aims to validate the potential of ECA-based lightweight concrete panels for sustainable building materials.

Advantages of ECA

Expanded Clay Aggregate (ECA) offers several advantages in various construction applications:

1. Lightweight: ECA is inherently lightweight due to its low density. This characteristic makes it an excellent choice for applications where weight reduction is critical, such as lightweight concrete, insulating concrete, and lightweight fill materials.
2. Thermal Insulation: ECA has excellent thermal insulation properties, making it suitable for use in insulating concrete and lightweight building materials. Its low thermal conductivity helps to reduce heat transfer through walls, floors, and roofs, thereby improving energy efficiency and reducing heating and cooling costs.
3. Acoustic Insulation: The porous structure of ECA provides good acoustic insulation properties, helping to attenuate sound transmission through walls and floors. This feature is beneficial for creating quieter and more comfortable indoor environments in residential, commercial, and industrial buildings.
4. High Strength to Weight Ratio: Despite its lightweight nature, ECA exhibits high strength and durability, making it suitable for structural applications in lightweight concrete and precast concrete products. Its high strength to weight ratio allows for the construction of strong and durable structures without adding excessive weight.
5. Non-combustible: ECA is non-combustible, meaning it does not contribute to the spread of fire. This property enhances the fire resistance of buildings and structures where ECA-based materials are used.
6. Chemical Inertness: ECA is chemically inert and resistant to chemical degradation, making it suitable for use in harsh environments and chemical exposure conditions. This property ensures the long-term durability and performance of structures containing ECA-based materials.
7. Environmentally Friendly: ECA is a natural, environmentally friendly material that is mined from natural clay deposits and processed using high- temperature kilns. It is inert, non-toxic, and recyclable, making it a sustainable choice for construction projects.
8. Versatility: ECA is a versatile material that can be used in various construction applications, including lightweight concrete, insulating concrete, lightweight fill, geotechnical applications, horticultural substrates, and more. Its versatility allows for innovative design solutions and the development of lightweight and sustainable building systems.

Objectives

The objective of this experimental study is to investigate the performance of lightweight concrete walls utilizing Expanded Clay Aggregate (ECA) as a partial replacement for traditional aggregates. The focus is on assessing the structural and thermal properties of the lightweight concrete. Lightweight concrete walls with ECA respond to varying loads, assessing their deformation characteristics, load-carrying capacity, and overall structural stability. Long- term stability of the lightweight concrete walls with ECA, considering factors such as creep and shrinkage, to ensure sustained performance over an extended period. The compatibility of lightweight concrete with ECA for use in reinforced structures, examining the bond strength between the concrete and reinforcement materials.

Scope

Benefit of ECA Precast Concrete Construction Wall Panel Light weight (Reduces the structural load by 40-50 %) Environment-friendly - "GREEN" alternative to traditional construction materials. Excellent thermal insulation properties Excellent sound or acoustic Insulation properties Superior compressive strength (earthquake resistant) Non-Reactive (strong chemical resistance against acidic and alkaline substances) Fire-resistant — EUROCLASS iResistant to water absorption Termite and pest resistant Easy to modify (can be carved, drilled, nailed and shaped easily) Concealed or conventional wirings and pipes installed with ease. Ease of coating with paint. Saves overall construction cost (mortar expense reduced to 70%) Coping vertically or horizontally NOT required Easy installation with regular cement mortar Time and labor saving solution.

Applications

Lightweight aggregate concrete is commonly used in various construction applications, including building construction, infrastructure projects, and precast concrete elements.

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:11/November-2024 Impact Factor- 8.187 www.irjmets.com

It is suitable for lightweight structural elements such as slabs, beams, and columns, as well as non-structural elements like partitions, cladding panels, and precast blocks.

Lightweight aggregate concrete is also used in applications where reduced dead load is desired, such as high-rise buildings, bridges, and roof structures.

Overall, lightweight aggregate concrete offers a versatile and sustainable solution for construction projects, providing benefits such as reduced weight, improved thermal insulation, and enhanced design flexibility.

Classification of aerated light weight concrete

Aerated lightweight concrete, also known as aerated concrete or cellular concrete, is a type of lightweight concrete that contains numerous air voids or bubbles throughout the concrete matrix. These air voids are created through the introduction of air or gas-forming agents into the concrete mixture during production. Aerated lightweight concrete offers several advantages, including reduced density, improved thermal insulation, and enhanced fire resistance. It can be classified based on various factors, including its production method, density, and intended application. Here's a classification of aerated lightweight concrete.

Study of light weight concrete

The study of lightweight concrete encompasses various aspects, including its properties, production methods, applications, and performance characteristics. Researchers and engineers conduct studies to understand the behavior of lightweight concrete under different conditions and to optimize its use in construction. Here are some key areas of study related to lightweight concrete:

Material Properties: Researchers study the physical, mechanical, and thermal properties of lightweight concrete, including its density, compressive strength, tensile strength, modulus of elasticity, thermal conductivity, and thermal insulation capabilities. Understanding these properties helps in designing lightweight concrete mixes for specific applications and optimizing its performance.

Mix Design and Proportioning: The study of lightweight concrete involves developing and optimizing mix designs to achieve desired properties such as strength, durability, workability, and density. Researchers investigate the effects of various factors, including types and proportions of lightweight aggregates, cementitious materials, water-cement ratio, chemical admixtures, and curing conditions on the performance of lightweight concrete mixes.

Production Methods: Researchers explore different production methods for lightweight concrete, including conventional mixing and curing techniques, as well as innovative approaches such as autoclaving, precast manufacturing, and foaming processes. Studying these methods helps in improving production efficiency, quality control, and cost-effectiveness of lightweight concrete production.

Durability and Performance: The durability of lightweight concrete under various environmental conditions, such as freeze-thaw cycles, moisture exposure, chemical attack, and aging, is a significant area of study. Researchers investigate the long-term performance of lightweight concrete structures and assess factors affecting their durability, such as porosity, permeability, carbonation, alkali-silica reaction, and corrosion of reinforcement.

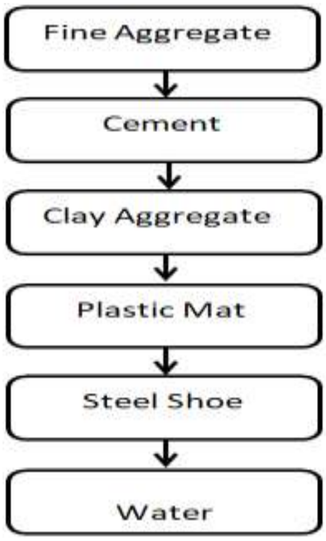
Structural Behavior: Researchers study the structural behavior of lightweight concrete elements, including beams, columns, slabs, and walls, under different loading conditions. This includes investigating factors such as load-carrying capacity, deflection, cracking, ductility, and fatigue behavior of lightweight concrete structures.

Energy Efficiency and Sustainability: Lightweight concrete is often studied for its energy efficiency and sustainability benefits, such as reduced embodied energy, lower carbon footprint, and improved thermal performance compared to conventional concrete. Researchers explore ways to optimize lightweight concrete mixes to enhance energy efficiency and sustainability in building construction.

Applications and Case Studies: Researchers conduct studies on the applications of lightweight concrete in various construction projects, including residential buildings, commercial structures, bridges, tunnels, and infrastructure projects. Case studies and field evaluations help in assessing the performance of lightweight concrete in real-world applications and identifying best practices for its use. Overall, the study of lightweight concrete is a multidisciplinary field that involves materials science, structural engineering, construction technology, and sustainability principles. Research in this area contributes to the development of innovative

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:11/November-2024 Impact Factor- 8.187 www.irjmets.com

lightweight concrete materials and construction techniques, leading to more efficient, durable, and sustainable built environments



Flowchart of light weight concrete wall panel

Experimental procedure of light weight concrete using eca

Experimental procedures for producing lightweight concrete using Expanded Clay Aggregates (ECA) typically involve several steps, including material selection, mix design, specimen preparation, casting, curing, and testing. Here's a general outline of the experimental procedure:

Material Selection: Select appropriate materials for the concrete mix, including cement, water, fine aggregates (such as sand), ECA, and any supplementary materials or chemical admixtures.

Mix Design: Determine the mix proportions based on the desired properties of the lightweight concrete, such as strength, density, workability, and thermal insulation.Conduct preliminary trials to optimize the mix design, adjusting the proportions of cement, water, and aggregates to achieve the desired performance.

Specimen Preparation: Prepare molds or formwork for casting the lightweight concrete specimens, such as cubes, cylinders, or prisms, according to the relevant testing standards (e.g., ASTM, EN).Clean and lubricate the molds to ensure easy removal of the specimens after casting.

Mixing: Measure and batch the materials according to the mix design proportions. Mix the cement, water, and fine aggregates thoroughly in a concrete mixer until a uniform paste is obtained.Gradually add the ECA to the mix while continuing to mix until all aggregates are uniformly coated with the cement paste.

Casting: Pour the mixed lightweight concrete into the prepared molds or formwork, filling them evenly to avoid segregation or honeycombing. Consolidate the concrete by tapping the sides of the molds or using a vibrating table to remove entrapped air and ensure proper compaction.

Curing: Cover the freshly cast specimens with plastic sheeting or wet burlap to prevent moisture loss and maintain adequate curing conditions.Cure the specimens in a controlled environment with constant temperature and humidity for the specified curing period, typically 7, 14, or 28 days, depending on the testing requirements.

Testing: After the curing period, carefully remove the lightweight concrete specimens from the molds.Conduct various tests to evaluate the properties of the lightweight concrete, including compressive strength, density, water absorption, thermal conductivity, and dimensional stability. Perform additional tests as needed to assess specific properties or performance characteristics of the lightweight concrete, such as flexural strength, modulus of elasticity, and durability.

Analysis and Interpretation:

Analyze the test results to assess the performance of the lightweight concrete and compare it to relevant standards or specifications.Interpret the findings to identify any factors affecting the properties or behavior of the lightweight concrete and make recommendations for further optimization or improvement.By following

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:11/November-2024 Impact Factor- 8.187 www.irjmets.com

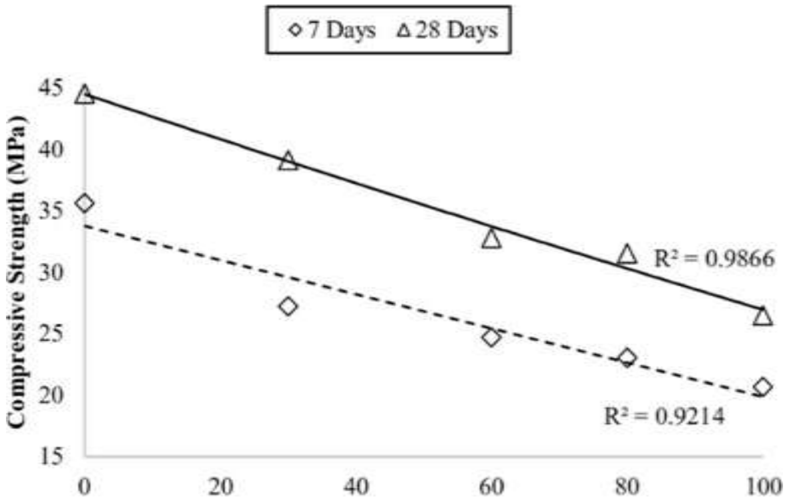
these experimental procedures, researchers can systematically investigate the properties and performance of lightweight concrete using Expanded Clay Aggregates (ECA) and contribute to the advancement of knowledge in this field.

Compressive Strength

Determining the compressive strength of lightweight concrete using Expanded Clay Aggregates (ECA) involves conducting compression tests on specimens prepared according to specific standards and procedures. Here's an outline of the general procedure for testing the compressive strength of lightweight concrete with ECA:

Compressive Strength = Maximum load/Cross sectional area of section

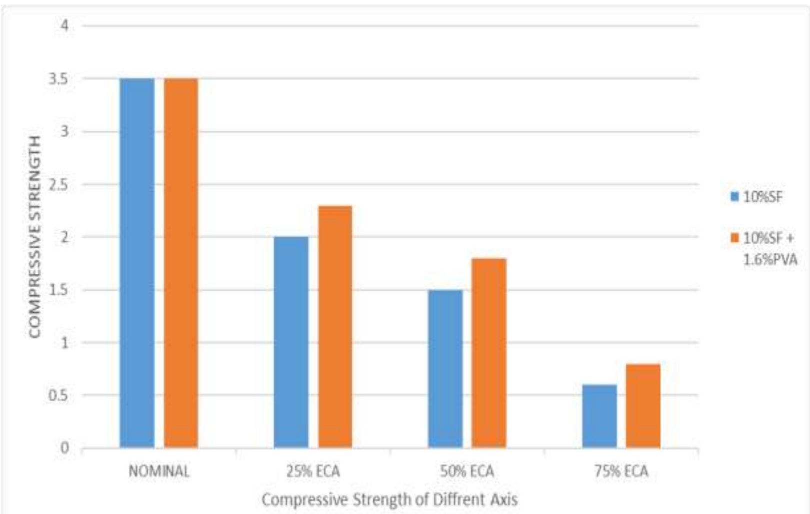
Percentage of ECA replacements(%)



Compressive strength of eca

S.NO	Coarse Aggregate Replacement in %	Compressive Strength For 10% Silica Fume (MPa)	Compressive Strength For 10% SF + 1.6%PVA (MPa)
1	Nominal	34.6	34.6
2	25% ECA	19.1	21.23
3	50% ECA	16.4	17.78
4	75% ECA	9.89	11.1
5	100% ECA	7.8	8.8

Compressive strength of different mixes



e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:11/November-2024 Impact Factor- 8.187 www.irjmets.com

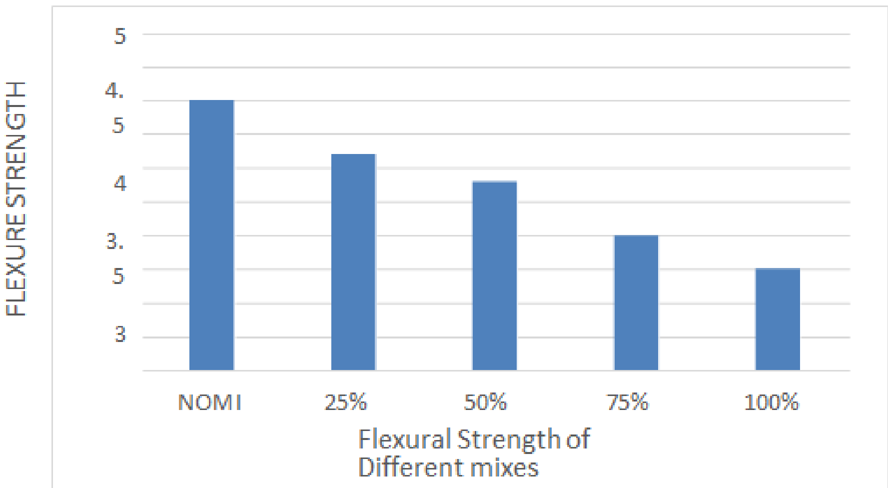
Flexural strength

1. Specimen Preparation: Prepare rectangular or square specimens of lightweight concrete wall panels according to the relevant testing standards (e.g., ASTM C1609, EN 12390-5).Use molds or formwork to cast the specimens, ensuring they are free from defects, such as voids, segregation, or surface irregularities. Consider the size and dimensions of the specimens based on the testing requirements and the expected behavior of the lightweight concrete wall panels.
2. Mix Design: Determine the mix proportions of the lightweight concrete based on the desired flexural strength and other performance requirements. Adjust the mix design to account for the properties of the ECA, including its particle size, shape, and density. Conduct trial mixes to optimize the mix design and ensure consistency in performance.
3. Casting: Mix the lightweight concrete ingredients thoroughly in a concrete mixer, ensuring proper coating of the ECA particles with the cement paste. Pour the mixed concrete into the prepared molds, filling them evenly and compacting the concrete to remove air voids, Tap the sides of the molds or use a vibrating table to ensure proper compaction and density of the specimens.
4. Curing: Cover the freshly cast specimens with plastic sheeting or wet burlap to prevent moisture loss and maintain a constant curing environment. Cure the specimens in a controlled curing chamber or water tank with constant temperature and humidity conditions for the specified curing period, typically 7, 14, or 28 days.
5. Testing: After the curing period, carefully remove the lightweight concrete wall panel specimens from the molds. Place the specimens in a flexural testing machine and align them properly to ensure uniform loading. Apply a load at the midpoint of the specimen at a constant rate (usually between 0.05 to 0.1 MPa/s) until the specimen fails in flexure. Record the maximum load applied and calculate the flexural strength of the lightweight concrete wall panel specimens using the formula: Flexural strength = 3*Maximum load*L/2*b*d^2

Flexural strength of eca

S.NO	Coarse Aggregate Replacement Proportion (%)	Percentage of cement Replaced with	Flexure strength (MPa)
1	Nominal	0%	3.91
2	25% ECA	10%SF+1.6%PVA	3.22
3	50% ECA	10%SF+1.6%PVA	2.68
4	75% ECA	10%SF+1.6%PVA	2.07
5	100% ECA	10%SF+1.6%PVA	1.45

Flexural strength of different mixes



e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:11/November-2024 Impact Factor- 8.187 www.irjmets.com

Where:

(L) = Span length (distance between supports)

(b) = Width of the specimen (d) = Depth of the specimen

Density

Determining the density of lightweight concrete wall panels using Expanded Clay Aggregates (ECA) involves measuring the mass and dimensions of the specimens and calculating the density using the formula:

Density = Mass/Volume

Specimen Preparation: Prepare rectangular or square specimens of lightweight concrete wall panels according to the desired dimensions and testing requirements. Ensure that the specimens are free from defects and have uniform thickness.

Weighing the Specimen: Weigh the lightweight concrete wall panel specimen using a calibrated scale or balance. Record the mass (weight) of the specimen in kilograms (kg).

Measuring the Dimensions: Measure the length (L), width (W), and thickness (T) of the lightweight concrete wall panel specimen using a tape measure or calipers. Record the dimensions in meters (m).

Calculating the Volume:

Calculate the volume (V) of the lightweight concrete wall panel specimen using the formula:

V = L *W *T Where,

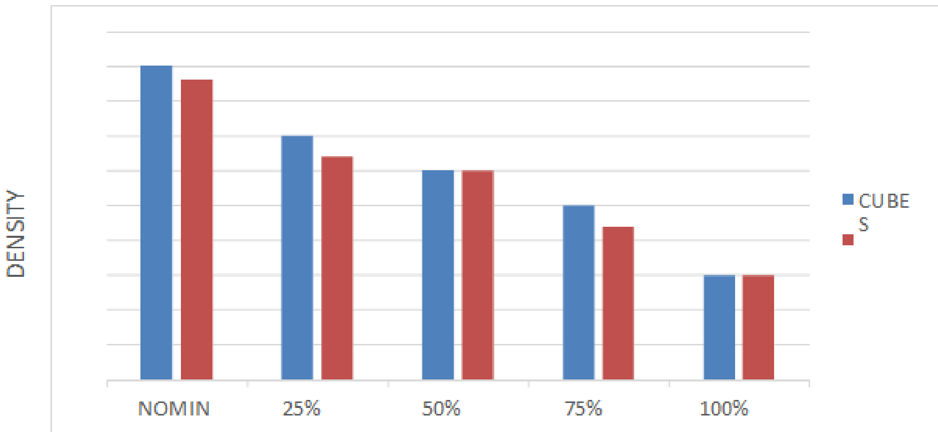
(L) = Length of the specimen (m)

(W) = Width of the specimen (m) , (T) = Thickness of the specimen (m)

Density of eca

S.NO	Coarse Aggregate replacement	Density of cubes for 10% SF + 1.6% PVA	Density of beams for 10% SF + 1.6%PVA
1	Nominal	2530.37	2408.25
2	25% ECA	2077.04	2168.89
3	50% ECA	1854.81	1893.97
4	75% ECA	1558.51	1690.16
5	100% ECA	1444.74	1456.16

Density of different mixes



Benefits of eca

Benefits of ECA precast concrete construction wall panel.

Benefit of ECA Precast Concrete Construction Wall Panel, Lightweight (Reduces the structural load by 40-50 %,Environment-friendly - "GREEN" alternative to traditional construction materials., Excellent thermal insulation properties, Excellent sound or acoustic Insulation properties, Superior compressive strength (

earthquake resistant),Non-Reactive (strong chemical resistance against acidic and alkaline substances),Fire-resistant – EUROCLASS 1, Resistant to water absorption, Termite and pest resistant.

Uses & Qualities of Portland Cement Portland cement is a widely used construction material., It is known for its excellent binding properties., It forms a strong and durable

Procedure

Weigh the sample to the nearest 0.1 g by total weight of sample. This weight will be used to check for any loss of material after the sample has been graded. Select suitable sieve sizes in accordance with the specifications.

Nest the sieves in order of decreasing size from top to bottom and begin agitating and shaking the sample for a sufficient amount of time.

For coarse aggregate, the large tray shaker is most commonly used (Figure 1).

This device provides a clamping mechanism which holds the sieve in place during agitation. Shakers of this make need to be run 5 minutes for size 9 or larger and 10 minutes for sizes smaller than size 9.

For fine aggregate, round 8" (203.2 mm) or 12" (304.8 mm) sieves are commonly used (Figure 2). These sieves are self-nesting and supported in a shaking mechanism at the top and bottom by a variety of clamping and/or holding mechanisms. Small shakers of this type require shaking times of 15 minutes to adequately grade the fine aggregate sample.

NOTE: Every effort should be made to avoid overloading the sieves. AASHTO defines overloading large sieves as weight retained in excess of 2.5 times the sieve opening in in. (mm), as expressed in gm/in.2 (kg/m2). For fine aggregate, no weight shall be in excess of 4 gm/in.2 (7 kg/m2).

1. Coarse Aggregates: After the material has been sieved, remove each tray, weigh each size, and record each weight to the nearest 0.1 g. Be sure to remove any aggregate trapped within the sieve openings by gently working from either or both sides with a trowel or piece of flat metal until the aggregate is freed. Banging the sieve on the floor or hitting the sieve with a hammer will damage the sieve. The final total of the weights retained on each sieve should be within 0.3% of the original weight of the sample prior to grading. Particles larger than 3 in. (75 mm) should be hand sieved. When passing large stones through sieves, do not force the aggregate through the sieve openings.
2. Fine Aggregates: Weigh the material retained on each sieve size to the nearest 0.1 g. Ensure that all material entrapped within the openings of the sieve are cleaned out and included in the weight retained. This may be done using brushes to gently dislodge entrapped materials. The 8 in. (203 mm) or 12 in. (304.8 mm) round sieves need to be handled with special care due to the delicate nature of their screen sizes. As a general rule, use coarse wire brushes to clean the sieves down through the No. 50 (300 μm) sieve (Figure 3). Any sieve with an opening size smaller than the No. 50 (300 μm) should be cleaned with a softer cloth hair brush (Figure 4). The final total of the weights retained on each sieve should be within 0.3% of the original weight of the sample prior to gradin.

III. MODELING AND ANALYSIS

Modeling of Concrete Panels: Finite Element Analysis (FEA) was used to model the behavior of lightweight concrete wall panels incorporating ECA. The model simulated the panel's response to various loads (e.g., compressive, flexural) and environmental conditions (e.g., temperature, moisture).

Material Properties: The material properties of ECA, including density, compressive strength, and thermal conductivity, were input into the model based on experimental data. A comparison was made with conventional concrete to assess the effect of ECA on overall panel performance.

Structural Analysis: The panels were analyzed for:

a. **Compressive Load**: To determine load-bearing capacity and failure modes.
b. **Thermal Behavior**: To evaluate heat transfer properties and insulation efficiency.
c. **Deflection and Stress Distribution**: To assess panel stability under applied loads.

Results of Modelling: The model predicted that ECA-based panels would experience lower stresses and deflections due to their reduced density. The thermal analysis confirmed better insulation properties than conventional concrete.

The modeling and analysis supported the experimental findings, showing that ECA panels perform well in terms of thermal insulation and structural behavior under moderate loading. The model also highlighted areas for potential optimization in mix design and panel thickness.

IV. RESULTS AND DISCUSSION

Compressive Strength: ECA-based panels showed lower compressive strength than conventional concrete, but still met requirements for non-load-bearing applications.

Density: A 25-30% reduction in density was observed, confirming the lightweight nature of the panels, which is ideal for reducing structural loads.

Thermal Insulation: The panels exhibited improved thermal conductivity, enhancing energy efficiency and making them suitable for insulating applications.

Water Absorption: ECA panels had slightly higher water absorption, indicating a need for additional treatments to improve durability.

Flexural Strength: Reduced flexural strength was noted, but still adequate for non-structural uses like partition walls.

ECA-based panels offer a good balance of reduced weight, better thermal insulation, and acceptable strength for non-load-bearing applications. While further improvements in durability are needed, they present a promising, sustainable material for energy-efficient construction.

V. CONCLUSION

The experimental study on lightweight concrete wall panels using Expanded Clay Aggregate (ECA) concludes that ECA-based panels offer a viable alternative to traditional concrete due to their reduced density, improved thermal insulation, and satisfactory compressive strength. The results demonstrate that incorporating ECA as a lightweight aggregate can significantly reduce the weight of concrete panels without compromising structural integrity. Additionally, the thermal conductivity of the panels shows promising potential for energy-efficient construction. The study highlights the suitability of ECA in producing sustainable, cost-effective building materials with enhanced thermal and mechanical properties, making them ideal for modern construction applications.

VI. REFERENCES

[1] T. Mohana Priya, Dr. M. Punithavalli & Dr. R. Rajesh Kanna, Machine Learning Algorithm for Development of Enhanced Support Vector Machine Technique to Predict Stress, Global Journal of Computer Science and Technology: C Software & Data Engineering, Volume 20, Issue 2, No. 2020, pp 12-20

[2] Ganesh Kumar and P.Vasanth Sena, "Novel Artificial Neural Networks and Logistic Approach for Detecting Credit Card Deceit," International Journal of Computer Science and Network Security, Vol. 15, issue 9, Sep. 2015, pp. 222-234

[3] Gyusoo Kim and Seulgi Lee, "2014 Payment Research", Bank of Korea, Vol. 2015, No. 1, Jan. 2015.

[4] Chengwei Liu, Yixiang Chan, Syed Hasnain Alam Kazmi, Hao Fu, "Financial Fraud Detection Fluid: Based on Random Forest," International Journal of Economics and Finance, Vol. 7, Issue. 7, pp. 178-188, 2015.

[5] Hitesh D. Bambhava, Prof. Jayeshkumar Pitroda, Prof. Jaydev J. Bhavsar (2013), "A Comparative Study on Bamboo Scaffolding And Metal Scaffolding in Construction Industry Using Statistical Methods", International Journal of Engineering Trends and Technology (IJETT) – Volume 4, Issue 6, June 2013, Pg.2330-2337.