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Durability and Microstructure studies of Plastic Incorporated Light Weight Concrete: A Review

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Abstract - **In the construction business, the introduction of light weight concrete has been a game changer. This paper summarizes the latest research and trends of Aerated concrete. The purpose of this work is to investigate the durability and microstructure of plastic-incorporated light-weight concrete. AC is a new concrete masonry material that is light weight, simple to construct, and transportable. This paper examines the history, physical properties, manufacturing process, and test programme of aerated concrete, concluding that the strength and density of the blocks change with changes in the proportion of aluminium powder. The microstructure and content of void generation and curing determine the qualities of aerated concrete. Plastic being a waste material is used in different forms as a replacement and the different properties is observed and studied. The paper mainly concentrates on the durability and microstructural studies of aerated concrete when different type of plastics are used, admixtures are used and when the percentage being replaced are varied according to its characteristic properties.**

***Keywords* — Aerated concrete, durability, microstructure, plastic, properties, construction.**

I. INTRODUCTION

Architects, engineers, and builders use aerated concrete in their construction projects. It's also a good material because of its great energy efficiency, fire resistance, and cost effectiveness. AC is a light-weight, flexible concrete that is commonly used as blocks. AC is made by mixing a specific amount of aluminium powder and other additives into a slurry of high-silica sand, cement, lime powder, and water. Aerated concrete (AC) is a widely used building material around the world. The addition of aluminium powder changed the strength and density of the material in a remarkable way. It has a 50-year track record of performance and may be used in any environment for any style of structure (Witt Mann, 1983, 1992). Since then, aerated concrete has been produced and used in more than 40 nations across the globe, including North, Central, and South America, Europe, the Middle East, the Far East, and

Australia. This extensive expertise has resulted in several case studies of the application in various climates and under various construction codes. AAC was first used in the United

States in 1990 for residential and commercial constructions in the Southeast. The studies by (Johan Alexanderson 1979) investigated the relationship between structure and mechanical properties of autoclave aerated concrete, discovering that the strength of aerated concrete, particularly cement and lime mixture, rose as the number of hydrates grew and the porosity decreased.

II. LIGHTWEIGHT CONCRETE

- It is a mixture made with lightweight coarse aggregates such as shale, clay, or slate, which give it its characteristic low density. It is a versatile and transportable construction material. (Agarwal et al., 2021) It's becoming more popular as a foundation material, and it's proving to be a viable alternative to normal concrete. There are numerous definitions of lightweight concrete, resulting in a lack of specificity when discussing the material. There are differences in the strength, density, and type of lightweight concrete coated. The basic principle behind the manufacturing of lightweight concrete is by inducing the air in concrete. To do this there are several methods that can be adopted, conventional aggregates in the concrete can be replaced by cellular porous aggregates. (Lightweight aggregate concrete). The air or gas bubbles can be inserted in concrete (Aerated concrete). During the preparation of concrete, sand should not be used and it should be omitted. (No- fines concrete). The ACI 213R-14 "Guide for Structural Lightweight-Aggregate Concrete" calls for a minimum cylinder strength of 17 MPa and an equilibrium density of 1120 to 1920 kg/m3 for structural lightweight concrete (SLC), and an equilibrium density of 800 to 2240 kg/m3 for specified density concrete without any strength requirements (SDC). SLC is categorised as high strength lightweight concrete when it has a compressive strength of 40 MPa after 28 days. (Christian Thienel et al., 2020) However, because it necessitates the addition of extra pozzolans and water reducing admixtures to the concrete, this may weaken the mixture's density.

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During the preparation of design mix of lightweight concrete it is very difficult to decide water- cement ratio of the concrete, due to variable water absorption by aggregates. It is usually done by trial mixing. Pre-saturation of aggregates is done to avoid excessive absorption of water by aggregates. Concrete in which saturated aggregates are present will have higher density, which is bad in freezing & thawing action. In rare cases, aggregates are coated with bitumen to overcome the water absorption problem. It is a cost effective alternative to traditional concrete, especially because the structure's strength is not compromised. Because of its higher porosity, LWC has a lower thermal conductivity, ideal for projects that prefer heat insulation.

III. AERATED CONCRETE

AC is a lightweight concrete that is manufactured by incorporating gas into the concrete during the mixing process (Wongkeo et al., 2012). Air-voids are allowed to be entrapped in the mortar by an appropriate aerating agent in aerated concrete, which is either a cement mortar or lime mortar categorised as lightweight concrete. The main benefit of AC is its light weight, which allows for more efficient construction of supporting structures like as foundations and lower-floor walls. Because of the porous structure, it provides excellent thermal insulation and significant material savings. Although it was originally intended as an insulating material, research in its structural properties has resurfaced due to its reduced weight, material savings, and potential for large-scale use of wastes such as pulverised fuel ash. Because of its low density and low thermal conductivity, AC is employed in building construction (Sari and Sani et al., 2017). The density of AC ranges from 800 kg/m3 to no more than 2000 kg/m3. Normal concrete (NC), on the other hand, has a density ranging from 2320 kg/m3 to 2400 kg/m3 and a compressive strength of 27 to 41 MPa (Lindeburg et al., 2017). Because it do not contain coarse material, as it is practically homogeneous when compared to traditional concrete. As a result, when compared to regular concrete, it has a wide range of qualities. The qualities of aerated concrete are determined by the curing procedures used, the pore organisation techniques used, and the microstructure and composition presented. Although hydrogen peroxide, bleaching powder, and calcium carbide, which liberate hydrogen, oxygen, and acetylene respectively, are the most commonly used air-entraining specialists, aluminium powder is widely used. (K. Ramamurthy et al., 2000) The workability of Aluminium powder is greatly lowered, and the fineness as well as the water-binder ratio also affect the aeration characteristics. The latest innovation in aerated concrete is Autoclaved Aerated Concrete (AAC). The Autoclaved aerated concrete (AAC) is a product of fly ash which is mixed with lime, cement, and water and an aerating agent. The AAC is mainly produced as cuboid blocks and prefabricated panels. The Autoclaved aerated concrete is a type of concrete that is manufactured to contain lots of closed air voids. The AAC blocks are energy efficient, durable, less dense, and lightweight. It is manufactured by adding a foaming additive to concrete in different sizes of molds as per requirement, then wire-cutting these blocks or panels from the resulting 'cake lump' and 'heating them with steam. This process is called as Autoclaving. It has been observed that this material is an eco-friendly building material that is being manufactured from industrial waste and is composed of non-toxic ingredients. Autoclaved Aerated Concrete (AAC) is a non combustible, lime based, cementitious building material that is expanding into new worldwide markets. Nowadays use Of AAC block significantly increase due to low cost and easy structure. Also another impressive factor about AAC is that no curing is required neither for AAC blocks or adhesive. High tensile strength is achieved in less time. Also as the thickness of the adhesive is very thin, it eliminates the shrinkage cracks in joints which further adds to the advanatges of AAC.

IV. PLASTIC AS REPLACEMENT

Plastic usage has increased throughout time as a result of its low cost, flexibility, and durability, as well as worldwide industrialization. (Josiane Nikiema, Zipporah Asiedu et al., 2022) Because of the slow pace of decomposition and the vast volume of plastic trash produced by human activities, massive landfills are necessary. Reusing plastic wastes in concrete as a natural aggregate replacement has recently been proposed as a way to lessen the exploitation of natural resources while also reducing construction's negative environmental implications. As a result, it is conceivable to use plastic trash as a substitute for natural aggregates because it is both cost-effective and environmentally beneficial. (Lei Gu, Togay Ozbakkaloglu et al ., 2016) Plastic aggregates and plastic fibres are the most common types of plastic used in concrete. Plastic aggregates are more cost-effective and simpler to use than fibres since they require fewer processing stages.

For concrete applications, various forms of plastic waste aggregates are available. PET is a polyethylene terephthalate (PET) that is commonly used in the United States and is thrown after one use. PET is commonly used to make plastic bottles, food containers, and fibre for clothing. According to research, adding plastic particles in concrete can achieve strength levels comparable to that of standard concrete, which makes it suitable for construction purposes. According to (Alqahtani et al., 2016), PET could be used to replace cement in the construction of pavements and roads when great strength is not required. Several experiments were conducted to investigate the use of plastic trash to replace 10 to 30% of natural coarse particles in concrete. (Subramani and Pugal et al., 2018) found that a 20 percent substitution was optimal, since the

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compressive strength declined significantly as the plastic content increased. Despite this, the majority of studies simply swapped the plastic particles in concrete at random and evaluated the effects on mechanical and durability parameters.

Plastic aggregates modify the uniformity and homogeneity of mixture qualities such as workability and density when they are added to concrete. Experiments conducted by (Saikia, de Brito et al., 2012) revealed that the surface and texture of plastic particles affected the fresh concrete's workability. When compared to traditional concrete manufactured with natural aggregates, the smoother surface of plastic aggregates generated concrete with a larger slump. As a result of a bigger area of smooth surface, the slump increased as the quantity of plastic aggregates grew. It was also discovered that as the percentage of plastic aggregates replaced increased, the density of the concrete reduced correspondingly, as plastics have a lower density than natural aggregates.

In the study by (Indu et al., 2021) Polyvinyl Chloride granules which pass a 5mm screen size are utilised to make lightweight aggregate concrete with a density of roughly 1500kg/m3. The link between workability and waste PET bottle replacement ratio in lightweight concrete shows that workability increase by 52, 104, and 123 percent, respectively, when compared to conventional concrete at water-cement ratios of 45, 49, and 53 percent. The smooth spherical form and non-water absorption features of PET aggregates account for this rise. When fine aggregate is partially replaced with PVC granules, the slump value is maintained between 160-180mm. Due to the availability of free water in the mix, the quantity of plastic aggregate increases since plastic particles do not absorb water as well as conventional aggregates. As the particle content of the mix increases, the consistency of the mixture decreases.

(Saikia et al., 2014) investigated the concrete properties utilising three different types of Polyethylene Terephthalate aggregates. Fine plastic aggregates, coarse plastic aggregates, and pellet-shaped plastic aggregates are the three types. The replacement percentages are 5%, 10% and 15%, and it was discovered that compressive strength was more for pellet-shaped aggregates, with an average 30MPa at an early age (7 days of curing), and compressive strength improves by 18% at later ages (91 days). (Batayneh et al., 2015) studied the slump of concrete containing ground plastic and identified that the slump value falls as the plastic concentration increases. This property is also influenced by the shape of the plastics. Even if the concrete's strength (3MPa) is reduced when plastic materials are used as fine aggregate, micro-cracks are prevented. As a result, the density is reduced (on average 1200kg/m3), which is an additional benefit for lightweight concrete. With the merging of the bubbles, the pore size grew more conspicuous and uneven at all densities. The use of plastic trash in concrete can change the qualities of the concrete, allowing the waste to be reused and thereby reducing the use of natural resources.

The investigation was done by (Nursyamsi et al., 2016) using PET (Poly Ethylene Terephthalate) plastic trash. The PET plastic waste coarse aggregate is the outcome of the PET being heated to induce agglomeration, then cooled and crushed into aggregates of various sizes and gradations. The goal of this research was to assess the compressive strength of LC made with PET plastic waste as coarse aggregate and the impact of aggregate gradations on the concrete's compressive strength. The fineness modulus (FM) of coarse aggregate from PET plastic waste employed was found to be smaller, resulting in lighter concrete. The surface area and density of the PET plastic waste effect the compressive strength of the structural light concrete, which is influenced by the coarse aggregate gradation. (Praveen Mathew et al., 2013) assesses the appropriateness of recycled plastics as coarse aggregates in concrete and their benefits. Plastic aggregate parameters such as density, specific gravity, and aggregate crushing value were determined by tests. The effects of partial replacement at various percentages were investigated. Other parameters such as modulus of elasticity, split tensile strength, and flexural strength were determined using the percentage substitution that yielded better compressive strength.

(Chio et al., 2012) investigated the replacement of sand with Poly Ethylene Terephthalate aggregates, which were formed of Poly Ethylene Terephthalate particles and stone powder, and found that the unit weight was reduced while water absorption increased. The results also demonstrate that as the proportion of PET aggregates substituted grows, the flow value increases. This is due to the round and slick surface of PET aggregates, which reduces friction between the mortar and the aggregates. Optimization By Plastic Granules: Plastic granules are used to partially replace fine aggregate in aerated concrete cubes at dosages of 5%, 25%, 50%, 75%, and 100%. PVC granules were employed as the fine aggregate. It's made by pulverising leftover PVC pipes into fine granules. After filtering through a 2mm and 90 micron sieve and removing the finer dust, the granules are used. PVC granules have a specific gravity of 0.786, according to research. All of the cubes are cast for a 7-day and 28-day period. It's important to keep track of the densities and compressive strengths.

V. EXPERIMENTAL PROGRAMS

A. FRESH PROPERTIES OF CONCRETE

- **Spread Test of Mortar**

The spread test is done as per (IS 1199 (1959): Methods Of Sampling And Analysis Of Concrete) used to find the fluidity of high slump concrete mixes quickly. A

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appropriate foundation, a conventional slump cone, a metal scoop, and a metric rule are all required for the spread test. With a lateral dimension of not less than 600mm, the base should be clean, level, smooth-surfaced, stiff, and non-absorbent. During the test, it should be level and vibration-free. As a base, a levelled ceramic tile has been employed. A tiny slump cone mould was used instead of the standard slump apparatus.

- **Marsh Cone Test**

The high-range water reducer employed is the Master Glenium Sky 8233. At 25°C, it is a light brown liquid with a relative density of 1.08. The Marsh cone test is used to identify the best super plasticizer dosage for various types of cements. The time it takes for a given amount of cement paste to flow out of the cone is measured in a marsh cone test. As per (IS 1199 (1959): Methods Of Sampling And Analysis Of Concrete) the March cone test was carried out. By adjusting the amount of super plasticizer, different pastes can be created. The fluidity of the tested material is linked to the measured flow time. The lower the fluidity, the longer the flow time.

B. HARDENED PROPERTIES OF CONCRETE

- **Compressive Strength**

The test is carried out in relevance with (IS 516:1959). Clean the testing machine's bearing surface. Place the specimen in machine, such that the load is applied to the cube cast's opposite sides. Align the specimen at the centre of the machine's base plate. Gently rotate the movable piece so that it touches the specimen's top surface. Apply the load gradually, without jarring the specimen, and at the required rate until it fails. Make a note of the maximum load obtained and any unexpected characteristics in the type of failure observed.

- **Density of the Mix**

Wet and dry densities of each mix containing varying quantities of aluminium powder were determined and compared after the mix was prepared. Wet density is calculated by weighing each mould filled with mortar mix and dividing the weight by volume of mould. The cube specimens must be dried to a constant mass before being cured for 7 and 28 days, respectively. The dry densities of mortar cubes are determined by weighing the dried cube specimens, and the process is repeated after 7 and 28 days of curing.

C. DURABILITY PROPERTIES OF AERATED CONCRETE

Durability Test Resistance Against Acid Attack

For acid attack test concrete cube of size 150×150×150 mm are prepared for various percentages of silica fume addition. This test was carried out in relevance to the findings of (Dr. S.M. Gupta., 2015) experiments on the strength and durability characteristics of concrete adding silica fume as an addition. The specimens are cast and cured in the mould for 24 hours, after which they are demoulded and preserved in the curing tank for seven days. After 7 days, all specimens are weighed and immersed in a 5 percent sulphuric acid (H2SO4) solution for 60 days to maintain a steady weight. The acidic media had a pH value of 0.3. The pH level was monitored on a regular basis and kept at 0.3. The specimens were removed out of the acid solution after 60 days and cleaned with running water before being stored in the environment for two days to maintain a steady weight. Following that, the specimens were weighed, and the weight loss was calculated as a percentage loss.

D. MICROSTRUCTURAL PROPERTIES OF AERATED CONCRETE

The mechanism of pore production (e.g., gas release or foaming) has an impact on the microstructure and thus the characteristics of aerated concrete. (Alexanderson J et al., 1979) Aerated concrete's material structure is defined by its solid micro porous matrix and macropores, according to research. The macropores emerge as the mass expands owing to aeration, while the micropores appear in the spaces between the macropores. Macropores are defined as pores with a diameter more than 60 micrometres. Due to the existence of voids, the orientation of cement hydration products is dramatically affected. (Petrov et al., 1994) The porous system of AC is also classed as artificial air pores, inter-particle pores, and intercluster pores in terms of pore size distribution functions, and the distribution of pores in the matrix has an impact on its properties.

(K.Ramamurthy et al.,2000) report on the structure of cement-based concrete (AAC) and non-AAC with sand or fly ash as the filler was used in this study. XRD was used to do a compositional analysis. The creation of Hadley grains and fly ash hydration are used to discuss the process of pore refinement in fly ash blends. Interfacial transition zone (ITZ) was discovered when the paste void interface in AC was compared to the paste aggregate interface in normal concrete. The presence of C S H with various C/S ratios such as C2SH, C2SH (B), and C2SH (D) combined with portlandite is recognised by the XRD pattern of aerated concrete with sand. The existence of high lime-silicate gels, which do not contribute much to strength development, is indicated by greater C/S ratios. Fly ash serves as a nucleation location for the creation of cement hydration products. It also aids in the refining of capillary pores. The combined action of hollow shells or Hadley grains and the hydration mechanism causes a reduction in capillary porosity. The drying shrinkage increased in non AAC when the lime cement content and fly ash ratio are increased. In AAC, drying shrinkage is significantly reduced, indicating that drying shrinkage is a function of hydration products' physical structure. (Y.H.M. Amran et al., 2015) Pore internal structure is intimately related to

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cellular concrete performance in the hardened stage. The effect of fresh qualities in the mixture (primarily foam stability) on mechanical performance and physical properties requires an understanding of void size distribution, homogeneity, geometry, spatial distribution, and linkage. The most notable experimental investigations have detailed the internal microstructure of pores qualitatively, but they have not been able to present quantitative conclusions for pore connectivity or distribution.

E . SORPTIVITY

Sorptivity tests were carried out according to ASTM C1585, with specimens measuring 100 mm in diameter and 50 mm in thickness. The effects of aeration on the capillary sorptivity of the slurry were therefore measured in an experimental investigation. After 24 hours of storage in sealed condition, the specimens were demoulded and then cured at room temperature until the test age. This test procedure entails submerging specimens one flat surface in water and sealing the remaining surfaces to prevent moisture loss. Moisture sorption is measured by measuring mass gain over time. Sorptivity is defined as the rate at which moisture is absorbed into an aerated slurry. This test was done for two days to acquire a better understanding of the schematic time-history of capillary sorption.

F. ULTRASOUND PULSE VELOCITY

Using portable equipment, the (UPV) of aerated slurry was determined non-destructively. An ultrasonic pulse is created and sent to the concrete surface through the transmitter transducer in this test. The receiver transducer on the opposite side measures the time it takes for the pulse to pass through the aerated slurry. Each opposing face had 54 kHz transducers installed in the centre. The propagation period of ultrasonic waves transmitted through the 150 mm long cylindrical specimens was precisely determined to within 0.1 second. To achieve good contact, a thin couplant, a solid blue kaolin and glycerol paste was applied to the interface between the transducers and the slurry specimen surface. The time it took for the pulse to travel from the front to the back was automatically recorded. The UPV was measured 50 hours after the slurry was mixed. The UPV specimens were made from mixes with similar proportions to those used in previous studies, however, the mixes used for the UPV specimens were not the same as those used for other tests.

G. THERMAL CONDUCTIVITY

The thermal conductivity of the aerated mix test was determined after seven days using ASTM C177. For a temperature of 105°Celsius, specimens were kept to oven dry for 24 hours. To imitate outdoor and inside temperatures, the specimen was put between hot and cold plates with temperatures of 40 and 18 degrees Celsius, respectively. Temperatures on the hot and the cold plates, as well as heat flow, were measured throughout a 24-hour period. The results were utilised to calculate the thermal conductivity of aerated slurry once the process reached equilibrium.

H. SCANNING ELECTRON MEASUREMENT

The microstructural characteristics of aerated samples were evaluated using Scanning Electron Microscopy (SEM). Using a secondary electron (SE) detector, SEM observations were performed on a JCM-5000 NeoScope at an accelerating voltage of 10–15 kV. After 28 days, the investigations were carried out on the fracture surfaces of the paste of the samples.

VI. CONCLUSION

1. The physical properties and test programme of aerated concrete are investigated in this study, with the conclusion that the strength and density of the blocks change as the quantity of aluminium powder is changed. Aerated concrete's properties are determined by the microstructure and content of void creation and curing. Plastic, which is a waste product, is employed in various forms as a substitute, and the various features of aerated concrete are observed and examined.
2. Adding plastic particles to concrete alters the uniformity and homogeneity of mix qualities including workability and density. Experiments revealed that the surface and texture of plastic particles had an impact on the workability of fresh concrete. When compared to traditional concrete created from natural aggregates, the smoother surface of plastic aggregates generated concrete with a larger slump.
3. The qualities of concrete made with three different types of PET aggregates: fine, coarse, and pellet-shaped plastic aggregates. The replacement percentages are 5, 10, and 15%, and it was revealed that pellet-shaped aggregates have higher compressive strength, with an average of 30 MPa at an early age (7 days of curing), and compressive strength improves by 18% at later ages (91 days).
4. There is a higher need for more research on aerated concrete's resilience and microstructural studies. The most notable experimental investigations have detailed the internal microstructure of pores qualitatively, but they have not been able to present quantitative conclusions for pore connectivity or distribution. As a result, additional in-depth research into the internal structure of aerated concretes is still needed, especially as elements like mixture design, foaming agent, and curing type all have a substantial impact on porosity development.

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