

Physical and Chemical Properties of Epoxy Mold Compound as Replacement of Fine Aggregate in Lightweight Concrete as A sustainable Pontoon

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Abstract

Due to the growing amount of trash generated worldwide, there is a need for creative and environmentally friendly waste management strategies. This study investigates the utilization of waste epoxy molding compound (EMC) as a strengthening agent in lightweight polyurethane concrete to create environmentally friendly floating pontoons. The objective of the research is to determine the most effective proportion of fine aggregate to waste EMC to create lightweight polyurethane concrete. Additionally, the study will examine the physical and mechanical characteristics of the concrete. The study promotes environmental sustainability by integrating EMC, which reduces landfill waste and improves concrete's buoyancy, strength, and thermal insulation. The experimental findings indicate that the replacement of fine aggregate with waste EMC in polyurethane lightweight polyurethane concrete enhances its compressive strength, density, and buoyancy, rendering it appropriate for use in floating pontoon applications. The materials were characterized using advanced analytical techniques such as Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and X-ray Diffraction (XRD). This study provides evidence for the use of sustainable materials and adds to initiatives aimed at reducing waste, in line with the principles of a circular economy.

1. Introduction

The World Bank projects a staggering increase in global waste to 3.4 billion tons by 2050. This growth, coupled with the detrimental impacts of untreated waste, underscores the urgent need for sustainable waste management [3]. The US Environmental Protection Agency highlights the significant risks improper disposal poses, such as soil and groundwater contamination, ecosystem disruption, and public health threats (EPA, 2022). Landfills are becoming dangerous reservoirs of waste, with leachate polluting the environment and burning waste exacerbating climate change (WHO, 2022).

The circular economy presents a promising solution by promoting a closed-loop system where waste is converted into valuable resources. The construction industry is increasingly adopting circular economy principles, with recycled building materials gaining popularity. Habitat for Humanity (2023), the National Ready Mixed Concrete Association (2023), and the American Society of Civil Engineers (2023) report growing use of recycled plastic, bricks, timber, and concrete aggregate in construction.

However, certain materials like epoxy molding compound (EMC), widely used in electronics, pose significant environmental challenges due to their non-biodegradable nature. Studies by Singh et al. (2020) and J. Zhang et al. (2019) highlight the ecological and health risks of improper EMC disposal [1][2].

This research explores using waste EMC in lightweight concrete for floating pontoons, aligning with circular economy principles by diverting waste EMC from landfills and utilizing it in construction. Pontoons, essential in marine applications [12], benefit from lightweight, durable, and modular designs. Incorporating EMC in lightweight concrete can enhance buoyancy, weight, and thermal insulation while promoting sustainability by reducing sand usage and addressing electronic waste. EMC's resistance to chemicals and weathering further supports its suitability for marine environments

1.1 Problem Statement

The disposal of epoxy molding compound (EMC) as electronic waste poses a significant environmental risk due to its complex, non-biodegradable composition. Improper disposal in landfills results in long-lasting hazards, necessitating innovative waste management solutions. Lightweight concrete (LWC), while advantageous in durability and cost, is unsuitable for pontoons. Therefore, incorporating waste EMC into a lightweight concrete matrix reinforced with polyurethane offers a promising alternative.

Polyurethane concrete surpasses traditional LWC in strength and resilience, crucial for pontoons in demanding marine environments where resistance to chemicals, saltwater, and abrasion is essential. Its low weight enhances buoyancy, providing increased stability and load-bearing capability [4]. Utilizing waste EMC as an aggregate in polyurethane concrete promotes a sustainable waste management solution and potential cost savings. This approach aligns with circular economy principles, encouraging resource recovery while mitigating environmental impact. Incorporating waste EMC into polyurethane concrete for pontoon construction can address the limitations of traditional LWC, offering significant financial and environmental benefits for marine infrastructure.

2. Methodology

2.1 Material used

Ordinary Portland cement (OPC) from YTL Cement is utilized from UTHM Pagoh. The fine aggregate, sieved to standard sizes ranging from 0.075 mm to 5 mm, comprises natural sand or crushed stone dust. The Epoxy Molding Compound (EMC) waste, sourced from STMicroelectronics Sdn. Bhd., undergoes gradation adjustment to integrate with fine aggregate, enhancing the concrete's properties. The EMC waste is cleaned, oven-dried to remove excess moisture, and ground to a fine aggregate size range of 0.075 mm to 5 mm. The fine aggregate, suitable for pontoon applications, passes through a 5.0 mm sieve and is retained on a 0.075 mm sieve, with particle size distribution analyzed using BS 410:2008 standards. Lightweight Expanded Clay Aggregate (LECA), supplied by a local building materials specialist, meets BS EN 13055:2016 standards. LECA is cleaned, sieved to remove undesirable particles, and pre-soaked in clean water for 15 to 30 minutes to enhance workability before mixing with the cement. The polyurethane component is procured based on supplier specifications to create a two-component resin and hardener system suitable for concrete applications. To analyze the lightweight polyurethane concrete with waste EMC for its physical and chemical properties.

2.2 Design Mix Proportions

The experimental procedure for preparing the polyurethane concrete involved meticulous mixing of various components in designated proportions. First, the dry ingredients Portland cement, aggregate, LECA (lightweight expanded clay aggregate), and EMC (epoxy mold compound) were carefully weighed according to a mix design ratio of 3:1:1 (LECA: Fine aggregate: Cement). The fine aggregate was substituted with EMC at varying levels of 0%, 25%, 50%, 75%, and 100% of the fine aggregate ratio as shown in Table 1. The polyether polyol, a key liquid component, was then measured and combined with the pre-weighed cement at room temperature, with a water-to-polyurethane ratio of 0.5:1 relative to cement. This initial mixing, lasting one minute, ensured a thorough and uniform distribution of the cement particles within the polyol. The introduction of cement into the polyol increased the mixing resistance and viscosity of the blend. Finally, the pre-mixed combination of LECA, EMC, and fine aggregates was incorporated into the mixture, followed by another minute of continuous mixing to achieve

complete homogenization. This meticulous approach ensured the formation of a uniform and well-distributed polyurethane concrete composite.

Table 1 Lightweight polyurethane concrete ratio

Sample	Epoxy Mold Compound, EMC	Epoxy Mold Compound, EMC	Light Weight Expanded Clay Aggregate, LECA	Fine Aggregate	Cement	Polyurethane
A	0	0	3	1	1	0.5
B	25	0.25	3	0.75	1	0.5
C	50	0.50	3	0.50	1	0.5
D	75	0.75	3	0.25	1	0.5
E	100	1	3	0	1	0.5

2.3 Fresh, Harden, and Properties Functional

2.3.1 Density Test

The density test was conducted on concrete cubes containing ground EMC as a substitute for fine aggregate to determine their density. This assessment followed the guidelines outlined in BS 1881-114:1983, which provides instructions for estimating the density of solidified concrete. The dry weight of the lightweight concrete (LWC) and the volume were used in conjunction to calculate the density using Equation 3.1. After obtaining the density values for each concrete specimen, these values were averaged to obtain a single representative density value for the sample set.

$$\text{Concrete Density (kg/m}^3\text{)} = \frac{\text{Weight of sample (kg)}}{\text{Volume of Sample (m}^3\text{)}} \quad (1)$$

2.3.2 Buoyancy

The buoyancy test is a comprehensive procedure that evaluates the buoyant force and apparent density of Polyurethane Lightweight Concrete (LWC) specimens with Epoxy Molding Compound (EMC). This test adheres to the standard procedure outlined in the "Test Method for Measuring Displacement of Rigid Pontoon and Small Craft." [5] Initially, the dry weight of the LWC specimen is determined. The sample is then completely submerged in a water tank, and a load is placed on top to precisely measure the submerged weight. The buoyancy of the sample is subsequently calculated using the following formula.

$$\text{Buoyancy} = \text{Mass dry} - \text{Mass submerged} \quad (2)$$

2.3.3 Accelerated Carbonization Chamber Test

In the Accelerated Carbonation Chamber Test, the depth of carbon dioxide infiltration in concrete is assessed by measuring the reduction in concrete alkalinity. Concrete samples are meticulously ground to expose a test surface, and a pH indicator solution, such as phenolphthalein, is applied. This indicator changes color from pink/red to colorless as carbonation lowers the pH [6]. The carbonation depth is measured from the surface to the point where the color change occurs, indicating the extent of carbonation exposure. This depth, recorded in millimeters or inches, quantifies the degree of carbonation in the concrete.

2.3.4 Compressive Strength Test

A compressive strength test was applied to 50 × 50 × 50 mm cubic specimens on Days 7 and 14 per BS EN 12390-3:2003 using a Universal Testing Machine (UTM), which has a capacity of 50 kN at a speed of 2.0 ± 0.5 kN/s until the specimens were broken. The procedure is repeated for each concrete sample. After adding up all the individual measurements, the average compressive strength is determined by dividing the total by the number of concrete samples tested. This average gives a general idea of the compressive strength of the concrete under examination [7].

2.3.5 FTIR (Fourier Transform Infrared spectroscopy)

FTIR analysis of Epoxy Moulding Compound (EMC) to evaluate its suitability as a substitute for fine aggregate in lightweight polyurethane concrete, precautions must be taken to prevent contamination and maintain sample dryness. The sample should be positioned onto the ATR crystal with optimal contact and sufficient pressure, especially for solids. A high refractive index ATR crystal, such as zinc selenide (ZnSe), diamond, germanium, or silicon, is essential [8]. The ATR-FTIR instrument should be configured with an appropriate infrared radiation source and a detector to capture the partially absorbed infrared light. Data collection involves capturing the infrared spectrum of the sample, which is then analyzed to determine the molecular composition and chemical characteristics of EMC.

2.3.6 SEM (Scanning Electron Microscopy)

SEM analysis of crushed concrete samples, affix the sample to an aluminium stub using double-sided carbon stickers and conductive paint, ensuring proper adherence by lightly tapping the stub with tweezers to remove any loose particles. Handle the pin stub with tweezers to avoid contamination. Adjust the SEM voltage within the range of 1 to 30 kilovolts (kV) to facilitate analysis in various fields, including nanotechnology, alloys, metals characterization, semiconductors, polymers, and graphene. Achieve a resolution of 5 nm or lower for detailed investigation. Use detectors such as the secondary electron (SE) detector, backscattered electron (BSE) detector, or other available detectors on the COXEM SEM to capture detailed images of voids on the sample surface [9]. The microstructure of lightweight polyurethane concrete samples, incorporating polyurethane and ground EMC for floating applications, was analyzed using SEM at magnifications of x67, x100, and x500 to comprehensively document the distribution and measurements of the voids, providing insights into the samples' ability to float and overall structural integrity.

2.3.7 XRD (X-ray Diffraction)

Prepared fragmented concrete for X-ray Diffraction (XRD) analysis, pulverize it into a fine powder using a ball mill or mortar and pestle. Perform a sieve analysis using sieves ranging from 4.75 mm to 75 μm to categorize the powder by particle size, selecting the fraction typically less than 75 μm for XRD examination. Ensure the powder is thoroughly dry and free from moisture before mounting it on a sample holder or zero-background plate to prevent interference with results. Configure the XRD equipment with appropriate parameters, scanning from 10 to 80 degrees 2θ to obtain diffraction data [10]. Analyze the data using software to identify diffraction peaks, determine crystal structure, and lattice parameters, and detect any impurities present. Store the sample in a dry, airtight container to avoid contamination and preserve accuracy. XRD analysis of the polyurethane concrete mix with EMC substitution provides insights into the chemical composition and crystalline phases, crucial for understanding material structure and properties.

3. Results and Discussion

3.1 Density Test

This study assessed the density of lightweight polyurethane concrete cubes incorporating ground Epoxy Mold Compound (EMC) as a partial substitute for fine aggregate. Density tests were conducted on hardened specimens after 14 days of curing. Results (Figure 2) show a significant decrease in density with increasing EMC replacement.

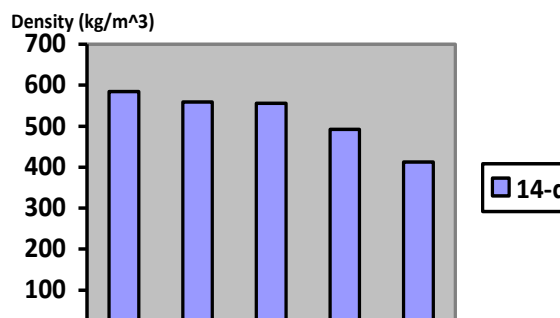


Fig. 2 Percentage of Grinded EMC versus Density

The highest density, 584.08 kg/m^3 , was observed in sample A (0% EMC replacement), indicating a dense packing of fine aggregates. As EMC content increased, densities decreased: sample B (25% EMC) was 558.96

kg/m³, sample C (50% EMC) was 556.00 kg/m³, sample D (75% EMC) was 492.40 kg/m³, and sample E (100% EMC) was 413.52 kg/m³.

The decrease in density can be attributed to EMC's characteristics, which introduce air spaces and less densely packed particles compared to fine aggregates. This confirms EMC's effectiveness in reducing concrete density, aligning with its role as a lightweight aggregate substitute. The uniformity of other constituents (cement, water, polyurethane, and LECA) across samples ensures that density variations primarily stem from EMC content.

3.2 Buoyancy

The buoyancy test is a crucial method for evaluating the buoyant properties of lightweight polyurethane concrete, particularly when incorporating ground EMC components. This study aims to assess the permeability and water absorption of lightweight polyurethane concrete samples with varying levels of EMC replacement.

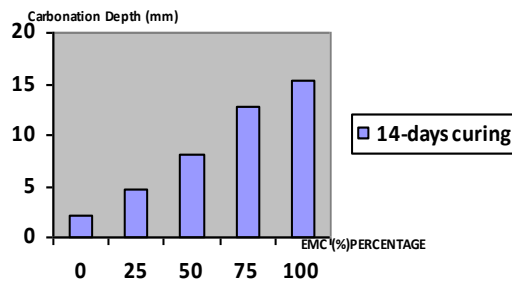


Fig. 3 Percentage of Grinded EMC versus Maximum Load

The results reveal a clear relationship between the percentage of ground EMC replacement and the maximum load capacity of the concrete specimens. Sample A, without EMC replacement, supports a maximum load of 634 grams, while Sample E, with complete EMC replacement, demonstrates a significantly enhanced capacity of 1275 grams—more than double that of Sample A.

Interestingly, the density of the concrete shows a converse relationship with its load-bearing capacity. Sample A, with the highest density at 584.08 kg/m³, exhibits the lowest load capacity, whereas Sample E, with a lower density of 413.52 kg/m³ due to EMC inclusion, shows the highest load-bearing capability. This highlights the beneficial impact of incorporating ground EMC on enhancing the load-bearing capacity of lightweight polyurethane concrete.

In conclusion, the findings suggest that lighter concrete mixtures, achieved through EMC incorporation, not only reduce density but also significantly improve load-bearing performance. This correlation underscores the potential for optimizing concrete formulations to achieve superior structural strength and buoyant characteristics.

3.3 Accelerated Carbonization Chamber Test

Data from the carbonation acceleration chamber test provide valuable insights into the impact of integrating Epoxy Molding Compound (EMC) as a partial substitute for fine aggregate in lightweight polyurethane concrete. The primary objective is to investigate how different proportions of EMC affect carbonation resistance and, consequently, the concrete's long-term durability.

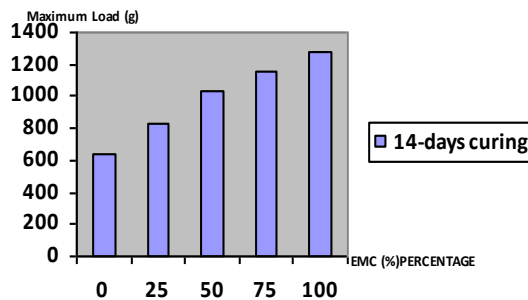


Fig. 4 EMC percentage versus Carbonation Depth

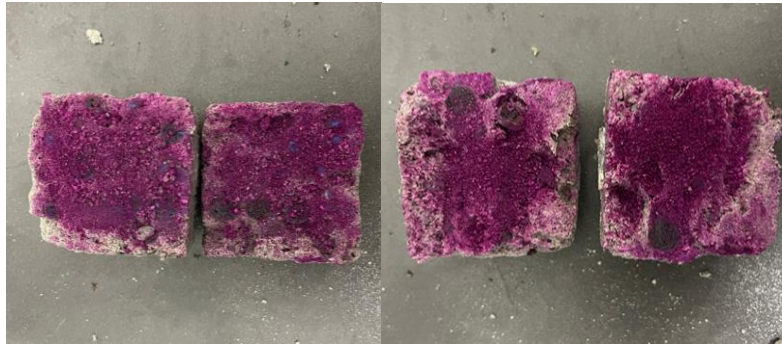


Fig. 5 Carbonation depth of 2.1mm(left) and 12.7mm (right)

Initially, the baseline concrete sample, without any EMC substitution, exhibited a carbonation depth of 2.1 mm (Fig 5). Standard concrete typically shows natural resistance to carbonation, making it suitable for various structural applications. Introducing 25% EMC resulted in a significant increase in carbonation depth to 4.6 mm, indicating that even a small amount of EMC can noticeably affect concrete's resistance to carbonation. The incorporation of EMC is expected to create more permeable areas within the concrete, facilitating easier CO₂ penetration.

At 50% EMC replacement, the carbonation depth increased further to 8 mm, suggesting higher permeability and reduced packing density due to increased EMC content, accelerating carbonation. At 75% EMC, the carbonation depth reached 12.7 mm (Fig 5), highlighting the substantial impact of EMC on concrete microstructure. As EMC content rises, the concrete becomes more heterogeneous, with increased voids and interfacial areas prone to carbonation. A complete substitution of 100% EMC resulted in the maximum carbonation depth of 15.3 mm, indicating reduced resistance to carbonation likely due to non-reactive and non-porous EMC particles disrupting the concrete matrix's integrity.

The data shows a clear correlation: higher EMC proportions lead to increased carbonation depth, underscoring the need for a balanced approach to maximizing EMC content in concrete mixes. While EMC offers advantages for certain properties, careful control is essential to manage its impact on carbonation resistance and ensure long-term concrete durability.

3.4 Compressive Strength Test

The compressive strength of concrete blocks at different ages, focusing on specimens aged for 7 and 14 days. The data compared a standard concrete block (control) with variations incorporating ground Expanded Mold Compound (EMC) at different percentages in Figure 6.

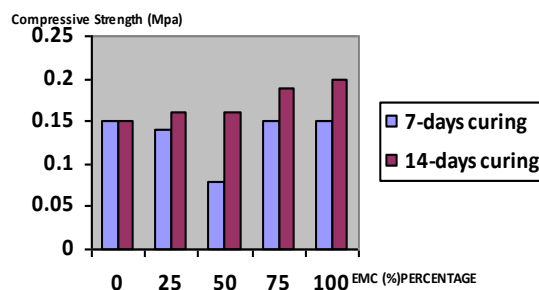


Fig. 6 Percentage of Grinded EMC versus Compressive Strength For 7 days and 14 days.

The findings revealed notable trends in compressive strength across different EMC percentages. At 7 days, the compressive strength remained consistent with 0% EMC (0.15 MPa) and 25% EMC (0.14 MPa), indicating that the addition of EMC up to 25% did not significantly impact the early-age strength of the concrete blocks. However, the compressive strength dropped significantly at 50% EMC (0.08 MPa), suggesting that higher EMC content (above 25%) can negatively affect the early-age compressive strength of the concrete blocks.

At 14 days, the concrete blocks exhibited varied responses to the incorporation of EMC. Slight increases in compressive strength were observed at 25% EMC (0.16 MPa) and 50% EMC (0.16 MPa), indicating that the addition of EMC up to 50% did not adversely affect the 14-day compressive strength. Interestingly, a distinct rise in compressive strength was noted at 75% EMC (0.19 MPa) and 100% EMC (0.2 MPa), surpassing the initial values observed at 0% EMC. These results suggest that incorporating EMC above 50% can potentially optimize the compressive strength of concrete blocks at 14 days.

At 7 days, another study indicated that the compressive strength of soil-cement blocks with varying amounts of waste tire steel fibers (WTSF) was satisfactory, as all the samples exceeded the minimum required compressive strength of 2 MPa as per the Brazilian standard [13]. Specifically, the blocks with 1.50% WTSF showed the highest compressive strength at 7 days [13].

Regarding the 14-day compressive strength, the search results show that the soil-cement blocks with 1.50% WTSF were able to meet the minimum compressive strength requirement of 4 MPa as per the Bolivian standard for building materials [13]. The blocks with 0.75% WTSF were able to meet this requirement after 28 days of curing [13].

The findings of this study provide valuable insights into the potential use of EMC in concrete block production. While the early-age compressive strength may be sensitive to higher EMC percentages, the 14-day results indicate that incorporating EMC above 50% can lead to enhanced compressive strength. However, it is crucial to consider factors such as durability and load-bearing capacity when applying these findings to practical applications, such as residential foundations. Further research may be necessary to fully understand the long-term performance and suitability of EMC-reinforced concrete blocks for various construction purposes.

3.5 FTIR (Fourier Transform Infrared spectroscopy)

The FTIR (Fourier Transform Infrared) analysis of the EMC (Epoxy Molding Compound) material has revealed several significant peaks that provide insights into the chemical composition and properties of the material.

Table 2 Peak and Intensity of FTIR Spectrum

Peak	Intensity	Functional Group
793.92	59.07	Aromatic
1025.0	100.00	C-O
1492	10.97	Aromatic

The prominent peak observed at 793.92 cm⁻¹ indicates the presence of aromatic compounds in the material. These aromatic structures contribute to the overall rigidity and mechanical strength of the EMC, enhancing its ability to withstand various stresses and deformations.

The highest intensity peak at 1025.02 cm⁻¹ corresponds to the C-O bond stretching vibrations, confirming the presence of epoxy groups in the material. These epoxy groups are crucial for the cross-linking process, which is essential for achieving the desired mechanical strength and durability of the EMC.

Another significant peak at 1492.80 cm⁻¹ suggests the presence of aromatic rings in the material. The aromatic rings contribute to the heat stability and chemical resistance of the EMC, making it suitable for applications that involve exposure to elevated temperatures or harsh chemical environments.

3.6 Scanning Electron Microscopy (SEM)

An in-depth analysis of lightweight polyurethane concrete samples used for floating applications was conducted using Scanning Electron Microscopy (SEM) to examine their microstructure [11]. Samples were observed at magnifications of x67, x100, and x500 to analyze the distribution and characteristics of voids within the material.

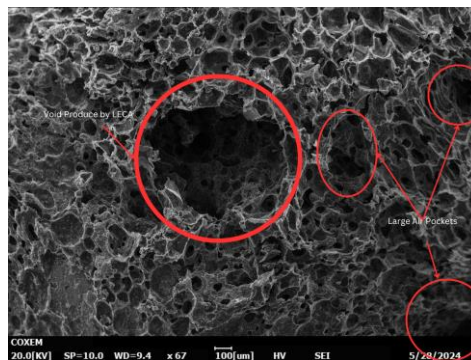


Fig. 7 Void area image with 67x Magnification

At x67 magnification, SEM images revealed a non-uniform distribution of voids throughout the material, varying significantly in size and shape. Larger voids (red circle) appeared as prominent cavities, while smaller ones were dispersed more densely. The majority of voids were round or elliptical, suggesting origins such as gas bubbles or inclusions trapped during processing.

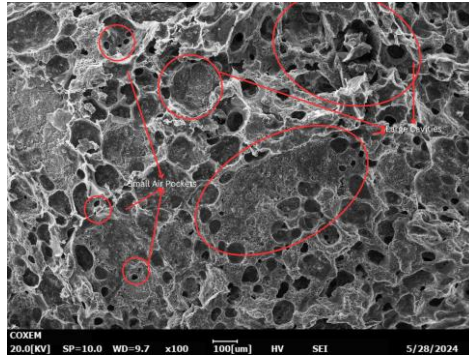


Fig. 8 Void area image with 100x Magnification

Increasing the magnification to x100 exposed a complex network of interconnected voids, ranging from large cavities (red circle) to tiny pockets. This porosity indicated potential pathways for fluid permeation, which could impact mechanical properties and buoyancy under different conditions.

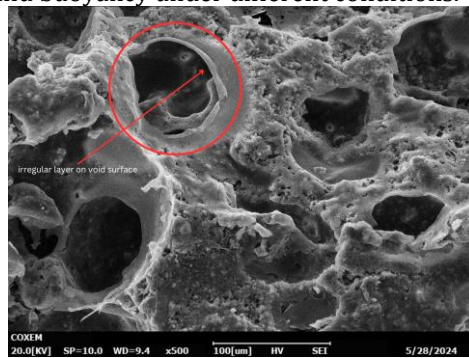


Fig. 9 Void area image with 500x Magnification

At x500 magnification, the SEM analysis highlighted a diverse range of void sizes and irregular shapes, from minute specks to expansive gaps. The walls of these voids exhibited varying textures (red circle), hinting at potential differences in strength. This detailed view underscored the material's heterogeneous structure and the potential implications for its mechanical performance and buoyancy.

Overall, SEM analysis provided critical insights into the void structure of lightweight polyurethane concrete, revealing significant heterogeneity and potential implications for its mechanical properties and buoyancy in practical applications.

3.7 XRD of Polyurethane Concrete

The XRD pattern reveals peaks corresponding to various compounds marked by colored lines and COD numbers Figure10: P6Rb4 (Red), Pb2Y (Green), Mg2P2S6 (Blue), K8Si4S6 (Orange), S2Si (Purple), CCa0.94Mg0.06O3 (Yellow), Ag1.049Mn0.901Pb3S12Sb5.049 (Pink), and P7Rh12Sr2 (Light Blue). Notably, magnesium calcite (Yellow line) is identified, suggesting calcite modification within the concrete matrix, potentially enhancing strength and durability.

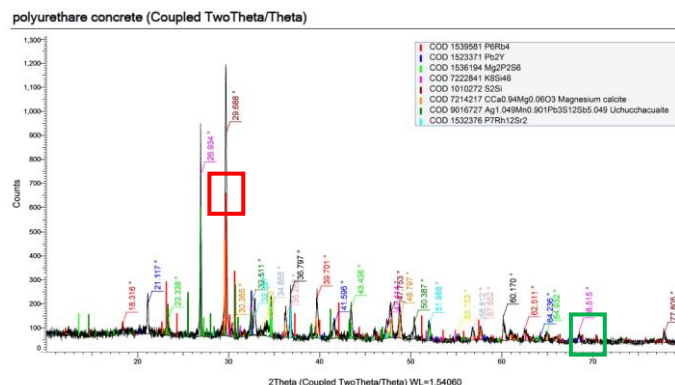


Fig. 10 Notable Component inside PU Concrete

The XRD scans highlight significant differences in crystallinity between the samples. The higher intensity peaks observed in the P6Rb4 pattern (red square) suggest a more well-defined crystal structure. This indicates that the polyurethane concrete has a highly ordered arrangement of atoms, potentially resulting from better polymer cross-linking or the presence of specific crystalline additives. These factors lead to a greater abundance of atoms that effectively diffract X-rays, hence the higher intensity peaks.

In contrast, the weaker peak intensities observed in the P7Rh12Sr2 pattern (green square) point to a less ordered crystalline arrangement. This could be due to a higher degree of amorphous regions in the polyurethane concrete, poorer polymer cross-linking, or the presence of filler materials that do not form a well-ordered structure. The lower concentration of atoms aligned for X-ray diffraction results in these weaker peaks.

These variations in peak intensity and position, marked by the red and green squares, provide valuable insights into the crystallographic characteristics and elemental compositions of the polyurethane concrete samples. The distinct differences observed in the XRD patterns can be attributed to variations in formulation and processing conditions, which affect the overall structure and properties of the material.

3.8 XRD of Polyurethane Concrete

The XRD analysis of the epoxy moulding compound (EMC) reveals a complex composition designed to enhance mechanical strength, thermal stability, and electrical conductivity (Figure 11), critical attributes for materials intended for concrete pontoons in marine environments. Components such as lazurite, bromo-chlorinated fullerene, and organic compound C16H11NS contribute significantly to improving structural integrity and heat resistance, which are essential for durability under fluctuating marine conditions.

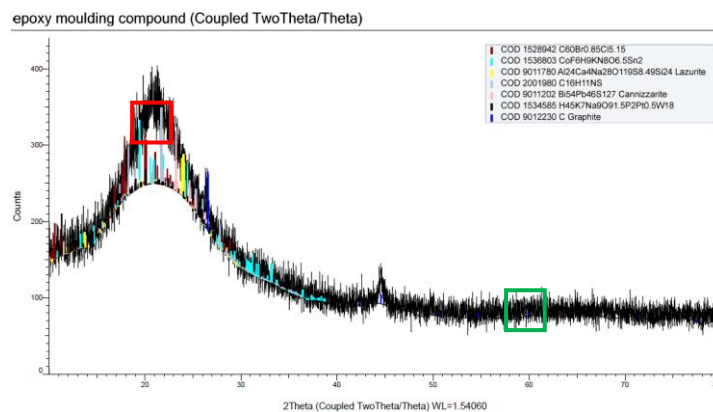


Fig. 11 Notable Component inside EMC

A significant peak in the XRD spectrum is attributed to bromo-chlorinated (red square) fullerene. This indicates the presence of carbon structures containing halogens within the EMC. The prominence of this peak suggests that these halogenated carbon structures are abundant and play a crucial role in the material's properties. The high intensity of this peak is likely due to the substantial amount of bromo-chlorinated fullerene in the EMC, which contributes to the material's stiffness and resistance to heat. These characteristics are essential for the EMC's performance in applications requiring high durability and thermal stability.

In contrast, the lowest peak (green square) in the spectrum is associated with graphite. The presence of graphite in the EMC implies that conductive additives have been incorporated into the material, potentially to enhance its electrical characteristics or improve thermal conductivity. The low intensity of this peak suggests that graphite is present in smaller quantities compared to other phases, indicating that while it is an important additive, it is not the dominant component. The inclusion of graphite, even in minor amounts, can significantly impact the EMC's performance by providing necessary conductive pathways and improving heat dissipation.

Concrete pontoons, as submerged structures, require materials that resist degradation and maintain stability over time. The incorporation of mineral fillers like lazurite can enhance these properties, but careful consideration of their environmental compatibility is necessary. Protective coatings or encapsulation techniques may be employed to minimize chemical leaching and reduce environmental exposure.

In conclusion, while the XRD analysis identifies materials with promising characteristics for enhancing concrete pontoons in marine environments, their environmental safety must be rigorously assessed and managed. Balancing technological innovation with ecological responsibility ensures that materials contribute positively to marine ecosystem health and sustainability, supporting resilient marine infrastructure development.

4. Conclusion

In conclusion, replacing fine aggregate with Epoxy Moulding Compound (EMC) in lightweight polyurethane concrete significantly reduces density, enhancing buoyancy suitable for pontoon applications. The density decreased from 584.08 kg/m³ in the control to 413.52 kg/m³ with 100% EMC. Buoyancy tests indicated a doubled load-bearing capacity with increased EMC content, but also highlighted increased carbonation and concerns for long-term durability. Compressive strength reached 0.2 MPa at 100% EMC, insufficient for structural use but promising for non-essential tasks. SEM analysis revealed abundant voids impacting mechanical properties. XRD and FTIR confirmed additives enhancing strength and thermal resistance. XRD analysis identifies beneficial additives but also reveals potentially hazardous compounds, necessitating careful environmental management. A 75% EMC ratio appears optimal for balancing performance attributes, emphasizing the need for further refinement to mitigate environmental risks associated with EMC use in marine applications.

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