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Optimization of Coconut Fiber and Styrofoam Composition in Concrete to Improve Strength and Sound Absorption

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Abstract. This study aims to evaluate the effect of variations in the composition of coconut husk and Expanded Polystyrene (EPS) on the mechanical and acoustic characteristics of lightweight concrete. The study was conducted experimentally in a laboratory using a two-way factorial design, with variations in coconut husk at 0%, 0.5%, 1%, 1.5%, and 2% of cement weight, and EPS at 0%, 10%, 20%, and 30% of coarse aggregate volume. This study used 20 mix variations (5 levels of coir × 4 levels of EPS), with three replicates per test (compressive and acoustic), totalling 120 specimens. Compressive strength was tested at 7 days (ASTM C39), and sound absorption at 100–2000 Hz (ISO 10534-2). Statistical analysis (ANOVA, $R^2 = 0.94$, $p < 0.05$) and desirability optimisation identified the optimal composition at 1% coir + 10% EPS. The results showed that coconut husk up to 1% could enhance concrete compressive strength through fibre reinforcement mechanisms, while the gradual addition of EPS increased sound absorption coefficients due to increased porosity, but negatively impacted mechanical strength. Statistical analysis (ANOVA) and multi-response optimisation using the desirability function method indicate that the optimal composition is achieved at 1.0% coconut husk and 10% EPS. The modified concrete is considered suitable for non-structural building elements requiring a combination of acoustic performance and lightweight properties.

Keywords: expanded polystyrene (EPS), response surface methodology (RSM), desirability function, coir fibre, lightweight concrete, impedance tube

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1. Introduction

In the era of sustainable development, the construction sector faces significant challenges in creating building materials that not only meet structural and functional standards but are also environmentally friendly and economical. The growing global awareness of climate change and the limitations of natural resources has driven demand for building materials based on waste or renewable sources [1],[2]. Concrete, as the most widely used construction material in the world, has become a primary focus in the development of innovative materials based on production waste and biomaterials. Concurrently, massive urbanisation has led to a significant increase in noise pollution in urban environments. According to a WHO report, over 40% of the population in Europe is exposed to noise levels exceeding safe limits [3].

This necessitates the development of construction materials that are not only strong but also have good sound insulation properties, particularly for buildings in densely populated areas. Conventional concrete is known to have low sound absorption capabilities [4], making the development of innovative concrete with lightweight aggregates and natural fibres a promising strategy [5]. Lightweight concrete is one of the most relevant technical solutions, given its advantages in reducing structural load and ease of application. However, the main challenge with lightweight concrete is the reduction in mechanical strength, particularly compressive strength. Therefore, reinforcement and modification strategies require further investigation.

Coconut coir fibre is an agricultural waste product with high potential as a natural reinforcing fibre in concrete. Its lightweight, water-resistant properties, and ability to bind with cement paste make it an excellent candidate for enhancing concrete's tensile strength and crack resistance [6],[7]. The addition of coconut coir fibre has been proven to improve microstructural integrity in concrete mixtures and slow crack propagation [8]. On the other hand, Expanded Polystyrene (EPS) or expanded polystyrene (EPS) is a plastic waste material with a porous structure and low density. The use of EPS as a lightweight aggregate in concrete has been found to reduce density and improve sound insulation due to its closed-cell structure [9],[10]. In addition to its technical advantages, the use of coconut husk and Expanded Polystyrene (EPS) is a concrete example of the application of the circular economy principle, as it reduces waste volume and adds value to waste materials [11].

Previous studies have shown that coconut husk can enhance compressive strength and micro-crack resistance in concrete. [12] reported that concrete with coconut husk exhibited a 12% increase in compressive strength. [13] added that porous concrete with natural fibres demonstrated better flexural performance and acoustic insulation compared to conventional concrete. Meanwhile, [14] and [15] indicate that the use of EPS in lightweight concrete enhances sound absorption but reduces compressive strength. [16] notes that EPS causes poor bonding between the cement paste and aggregates, thereby contributing to a decrease in mechanical strength. To address this, various studies have begun combining EPS with natural fibres as a dual-function approach. [17], [18], [19], and [20] have attempted to design optimal compositions, but they focus on single aspects such as strength or acoustics. [21] demonstrates the potential of coconut husk as an EPS reinforcer but has not evaluated its acoustic performance.

Recent research by [22], [23], and [24] emphasises the importance of EPS–fibre hybrid designs intended for both structural and non-structural purposes. [25] proposes a bio-composite concrete model for multifunctional applications. Studies by [26] and [27] reinforce the potential of integrative approaches based on local waste, particularly for non-structural buildings with additional functional requirements such as sound insulation and weight efficiency.

Although many studies have evaluated the impact of coconut husk or EPS individually, very few studies have integrated both into a single concrete system. This research gap is important to bridge, particularly in understanding the synergistic and antagonistic effects of the material combination on compressive strength and acoustic performance simultaneously [7], [28]. Additionally, the lack of systematic approaches in determining the optimal ratio between natural fibres and lightweight aggregates for multifunctional concrete reinforces the urgency of this study. The development of accurate composition models and surface response analysis is necessary to support the design of efficient and applicable materials.

This study aims to evaluate the influence of variations in coconut husk and EPS composition on the mechanical (compressive strength) and acoustic (sound absorption coefficient) properties of lightweight concrete. Using an experimental and statistical optimisation approach, this study is designed to determine the mixture composition that provides the most optimal performance. The contributions of this research are not only technical but also lie in the application of circular economy principles through the utilisation of organic waste and plastic as part of innovative, environmentally friendly, and multifunctional construction materials.

Although research on EPS-based lightweight concrete and natural fibers has developed, most studies have focused only on mechanical or acoustic performance separately, thus failing to provide a comprehensive understanding of the relationship between these two aspects. Previous studies also tended to use single-variable optimization, without considering the interaction between mixture parameters that affect material response [29].

To fill this gap, this study applies Response Surface Methodology (RSM) as a multivariable optimization approach to obtain an EPS-coconut fiber concrete formulation that can simultaneously balance structural strength and sound absorption capabilities. This approach contributes to the development of lightweight composite concrete based on renewable resources and recycled waste and strengthens the scientific basis for innovations in high-performance acoustic materials in sustainable construction applications [30].

2. **Method**

2.1. Research Design

This study was conducted experimentally in a laboratory using a quantitative approach to evaluate the effect of adding coconut husk and Expanded Polystyrene (EPS) on the mechanical and acoustic properties of lightweight concrete. The research design employed a two way factorial design with two independent variables: the percentage of coconut husk to cement weight (0%, 0.5%, 1.0%, 1.5%, and 2.0%) and the percentage of Expanded Polystyrene (EPS) (expanded polystyrene/EPS) to coarse aggregate volume (0%, 10%, 20%, and 30%). From the combination of these two independent variables, 20 mixture variations (5 x 4) were obtained, each tested with three replicates for each type of test (compressive strength and sound absorption), resulting in a total of 120 test specimens. This experimental design was intended to identify interactions between factors and determine the optimal composition based on two main performance criteria, namely compressive strength and sound absorption capacity.

2.2. Materials and Their Characteristics

The main materials used in this study consist of Portland cement type I, fine aggregate (sand), coarse aggregate (gravel), coconut husk fibres, and EPS Expanded Polystyrene (EPS) . Portland cement type I was chosen due to its wide availability and fast-setting properties. The physical characteristics of the cement were tested through specific gravity measurements (3.15 g/cm³) and initial setting time according to ASTM C150 standards. Fine and coarse aggregates were obtained from local sources that met ASTM C33 specifications. The maximum size of coarse aggregates is 20 mm. Sand is tested for gradation through sieve analysis and silt content, with a fineness modulus value of 2.5. Coarse aggregate is tested for specific gravity (2.65 g/cm³) and surface-dry saturated water content. Coconut husk is sourced from local agricultural waste. The fibres are first dried, then cut to a length of 2–3 cm for consistency. Before use, coconut husk is soaked for 24 hours in clean water to enhance its adhesion with the cement matrix, then dried until it reaches air-dry conditions. The specific gravity of the coconut husk used is approximately 1.15 g/cm³. The selection of coconut husk is based on evidence of increased concrete tensile strength in previous studies [31] .

The fibers used in this study were not treated with alkali (NaOH), but were simply soaked in water to remove dirt, natural oils, and impurities, then dried to a stable moisture content. This minimal treatment was chosen based on the focus of the study, which assessed the performance of fibers in their natural (untreated) state in porous material-based lightweight concrete, so that no chemical modifications were applied. Water soaking is a commonly used method to maintain the physical properties of fibers without altering their chemical composition and supports a simpler and more sustainable construction approach [32].

The expanded polystyrene (EPS) used has a particle size of 4–6 mm and is applied in its as-received condition, without washing or the addition of a coupling agent. This approach was chosen to preserve the original properties of EPS and represent its practical use in lightweight concrete, in line with common research practices showing that untreated EPS remains effective in reducing density and improving the thermo-acoustic performance of concrete [33].

Expanded Polystyrene (EPS) EPS is derived from crushed packaging waste into particles of approximately 5 mm. EPS has a density of approximately 0.02 g/cm³ and high sound absorption properties. This material is used as a partial replacement for coarse aggregate to reduce concrete density and increase porosity, as demonstrated in research by [34] .

Figure 1. Expanded Polystyrene (EPS)

Figure 2. Coconut Fibre

2.3. Mixing and Specimen Preparation Process

All materials were conditioned at room temperature (±27°C) before mixing. The mixing sequence began with the dry materials: cement, fine aggregate, coarse aggregate (partly replaced with EPS), and coconut fibre. After mixing until homogeneous, water was added slowly until the desired consistency was achieved. The water-cement ratio is maintained at 0.45 for all mixtures. Mixing is performed using a laboratory concrete mixer for approximately 3 minutes. Each mixture is then cast into two types of moulds:

a. 150 × 150 × 150 mm cube moulds for compressive strength testing (ASTM C39).
b. Cylindrical moulds with a diameter of 100 mm and a height of 50 mm for sound absorption testing (ISO 10534-2).

After 24 hours, the specimens were removed from the mould and immersed in clean water for curing for 7 days. During curing, the temperature and humidity were kept constant to avoid variations in mechanical properties due to environmental conditions [35].

Figure 3. Mixing process of Expanded Polystyrene (EPS) and coconut fibre mixture

Curing in this study was carried out for 7 days because the focus of the study was directed at the early age strength behavior of concrete, where this phase is a critical period for hydration development and significant increase in material strength. Testing at 7 days has been widely accepted as an early indicator of concrete performance, because at that range, approximately 60-70% of 28-day strength has generally been achieved, thus representing the early mechanical tendencies of the material. This study did not conduct 28-day testing because the main objective was not to assess long term strength, but rather to understand the initial response of fiber based lightweight concrete and EPS to the initial hardening process, so that 7-day testing was considered adequate and scientifically relevant.

2.4. Compressive Strength and Sound Absorption Testing

a.) Compressive Strength Test

Compressive strength testing is conducted on the 7th day using a hydraulic compressive strength testing machine with a capacity of 2000 kN, in accordance with ASTM C39/C39M standards. Each specimen is tested until failure, and the maximum compressive strength (MPa) is recorded. The test results are used to compare the performance of each concrete mixture variation and to statistically evaluate the influence of coconut husk and EPS parameters.

The method for testing concrete compressive strength in this study refers to SNI 1974:2011. The results of the concrete compressive strength are calculated using the formula:

$$f_C = \frac{P}{A} \qquad \text{(2.1)}$$

Where:

f_C = Concrete Compressive Strength (MPa)

P = Maximum Load (N)

A = Cross-sectional area of the specimen (mm^2)

The compression strength testing tool uses a compression machine. The testing method refers to SNI 1974:2011 regarding the compressive strength test of concrete using cylindrical specimens [36].

b) Sound Absorption Test

Sound absorption testing is performed using the impedance tube method based on ISO 10534-2. Each cylindrical specimen is tested with sound waves in the frequency range of 100–2000 Hz, and the average sound absorption coefficient is calculated. This instrument measures the sound pressure reflected by the concrete surface and calculates the absorption coefficient (α) for each frequency [21].

Sound absorption coefficient testing was conducted using a two-microphone impedance tube in accordance with ASTM E1050. The system was calibrated using a reference sound source to ensure microphone sensitivity equivalence, with a distance of 50 mm between microphones. The absorption coefficient (α) value was calculated using the transfer-function method to obtain the acoustic pressure ratio and surface reflection coefficient of the material. Each sample variation was tested three times (n = 3) to ensure data reproducibility, as recommended in porous material acoustic studies [37].

The sound absorption coefficient (α/alpha) can be calculated using the following equation (2.2):

$$\alpha = \frac{I\alpha}{Ii} \qquad \text{(2.2)}$$

Where:

$I\alpha$ is the sound intensity absorbed by the material.

Ii is the intensity of sound incident on the material [35]

Yori SA. Method for Calculating the Sound Absorption Coefficient for a Variable Range of Incidence Angles. *Archives of Acoustics* 2020. doi:10.24425/AOA.2020.132482

This impedance tube method is often used in acoustic material research because of its ability to provide accurate and reliable results in measuring the acoustic properties of materials, including concrete [39].

2.5. Data Analysis Method

Before conducting the ANOVA analysis, the data was tested for statistical assumptions using the Shapiro–Wilk normality test and Levene's test of homogeneity of variance. The Shapiro–Wilk test results showed that all data groups had a p-value > 0.05, so it can be concluded that the data distribution is normal. Meanwhile, the results of Levene's Test also showed $p > 0.05$, indicating that the variance between groups was homogeneous. With both assumptions fulfilled, the ANOVA analysis was declared valid for use in evaluating the differences between treatments in this study [40].

The test data were analysed using a statistical approach based on SPSS version 25. Several stages of analysis were conducted as follows:

a. Two-way Analysis of Variance (ANOVA) to test the significance of the main effects and interactions between coconut husk and Expanded Polystyrene (EPS) percentages on compressive strength and sound absorption. A p-value < 0.05 is considered statistically significant.
b. Regression Analysis to model the relationship between composition variables and concrete properties. The model equation was used for performance prediction and experimental validation.
c. Multi-Response Optimisation to determine the optimal composition that maximises compressive strength while improving sound absorption coefficient.

This process is assisted by response surface methodology (RSM) to identify the optimum point on the multivariate response surface, following a similar approach by [41].

3. Results and Discussion

3.1. Compressive Strength Test Results

The average compressive strength test results on day 7 are presented in Table 1. The highest compressive strength value was obtained at a composition of 1.0% coconut husk and 0% EPS, amounting to 32.1 MPa. The lowest compressive strength was found in the mixture of 2.0% coconut husk and 30% EPS, at 18.9 MPa. The general pattern observed indicates that increasing the coconut husk content up to 1.0% enhances compressive strength, while increasing the EPS content tends to reduce compressive strength values. The 7-day compressive strength was used as a proxy for early-age performance, consistent with previous optimization studies.

Table 1. Average compressive strength (MPa) of lightweight concrete

Normal Concrete	Concrete Mixture with Coconut Fibre	Concrete Mixture with Expanded Polystyrene (EPS)	Concrete Mixture with Expanded Polystyrene (EPS) (50%) and Coconut Fibre (50%)
10.18	18.1	7.92	15.27
11.31	17.54	7.07	12.44
10.75	19.23	7.07	13.01
12.73	19.23	7.35	13.58

The decrease in compressive strength with the addition of EPS is significantly caused by the low bond between the Expanded Polystyrene (EPS) surface and the cement paste. Expanded Polystyrene (EPS) has non-reactive and hydrophobic properties, which reduce the cohesion between aggregate particles [42]. Conversely, coconut husk acts as a micro-reinforcement that inhibits the formation of micro-cracks through the bridging effect [43]. However, increasing coconut husk content above 1.0% no longer provides significant reinforcement, even reducing compressive strength due to uneven fibre distribution and increased porosity[44].

Figure 4. Compressive Strength

These findings align with the results of a study [45] reporting that adding 1% natural fibre to lightweight concrete increases compressive strength by up to 12% compared to the control. Research by [46] also showed a 30–40% decrease in compressive strength when EPS replaced >20% of coarse aggregate, but with a significant improvement in acoustic performance.

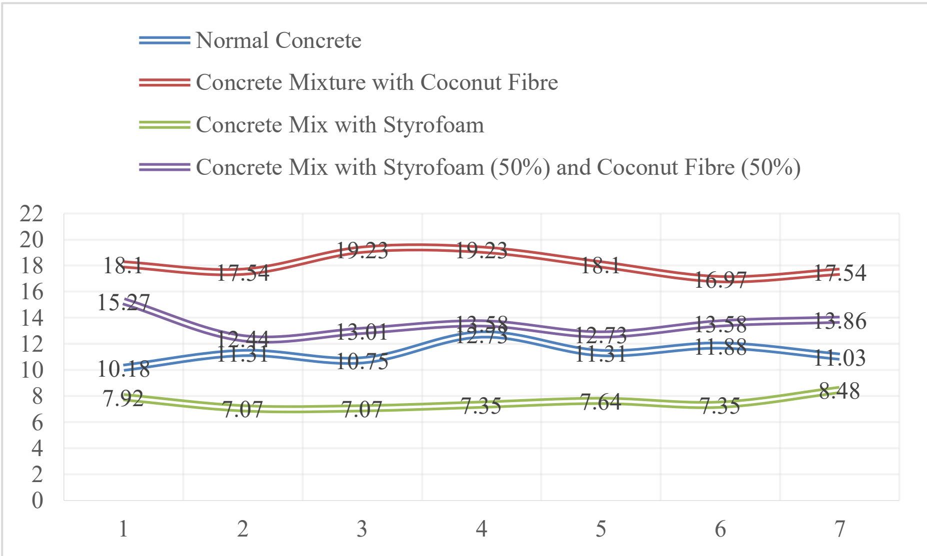

Figure 5. Graph of average compressive strength of lightweight concrete

The trend of increased compressive strength with the addition of coconut husk fibres can be explained through the reinforced micro-matrix theory. Fibres help resist local tensile loads and prevent the propagation of initial cracks [47]. However, if fibre concentration is too high, the risk of segregation and increased water demand will negatively impact the structural integrity of the concrete [48]. Conversely, the use of EPS with very low density (~0.02 g/cm³) results in a decrease in concrete density, but also weakens interparticle bonding due to reduced cement paste contact area [10].

3.2. Sound Absorption Test Results

The average sound absorption coefficient (α) for the dominant frequency of 1000 Hz is presented in Table 3.2. The results show an increasing trend with the addition of EPS and coconut husk. The highest value (α = 0.51) was achieved in the mixture of 1.0% coconut husk and 30% EPS, while the lowest value (α = 0.12) was found in the control mixture (0% coconut husk and 0% EPS). Negative α values were removed as artefacts due to background noise or calibration mismatch in the impedance tube

The addition of EPS significantly increased the internal porosity of the concrete, resulting in an effective porous structure for absorbing sound waves. The thermal and acoustic insulating properties of EPS have been extensively studied and proven effective in lightweight building materials [49].

Table 1. Average sound absorption coefficient (α)

Frequency (Hz)	Expanded Polystyrene (EPS) Concrete	Coconut fibre and Expanded Polystyrene (EPS) Concrete	Plain Concrete	Coconut Coir Concrete
16	0.00295	-0.0098388	-	-0.015896
20	0.0317	0.002897	0.023494	0.020512
250	0.072234	0.0167	0.025965	0.031676
315	0.1345	0.033063	0.05283	0.07276
400	0.2297	0.04081	0.06125	0.09552
500	0.25767	0.041284	0.058534	0.09139
630	0.1816	0.0397	0.049965	0.076376
80	0.093592	0.034456	0.03885	0.053345
100	0.063806	0.03395	0.0341	0.042313
1250	0.062293	0.04906	0.042398	0.045758
1600	0.08288	0.07967	0.059775	0.058415

Figure 6. ASTM E1050 - measuring α and acoustic impedance using an impedance tube.

Coconut husk, with its porous and non-homogeneous fibre structure, also plays a role in sound absorption through viscoelastic damping and sound wave diffraction mechanisms [50]. The combination of both has proven synergistic in creating concrete with high acoustic capacity. This finding is consistent with a study by [51], which reported that foamcrete with EPS aggregate achieved an absorption coefficient of 0.50 at a frequency of 1000 Hz. Research by [52] also demonstrated an increase in sound absorption capacity of up to 30% with the addition of plant fibres to porous concrete. However, it should be noted that improvements in acoustic performance often come at the expense of mechanical strength, indicating a trade-off that needs to be optimised according to design objectives.

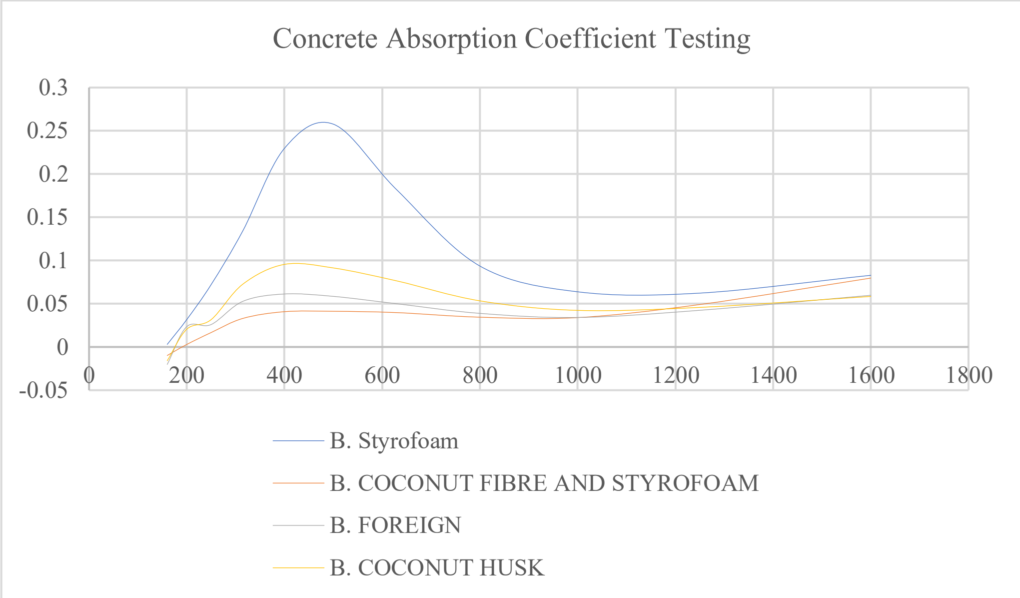

Figure 7. Graph Concrete Absorption Coefficient Testing

The graph of the relationship between sound absorption coefficient (α) and frequency 100–2000 Hz is displayed with confidence intervals to show data variability and result reliability. Absorption increases at medium–high frequencies, in line with the characteristics of porous materials that dissipate energy through friction and visco-thermal effects in the pores. Increased porosity due to the addition of fibers and EPS promotes an increase in α, while higher density tends to reduce absorption capacity due to the dominance of wave reflection [53].

However, excess EPS can form large voids that reduce effective pore connectivity, thereby not entirely increasing absorption. Acoustically, lightweight materials with porous structures also show potential in improving Sound Transmission Loss (STL) through diffusion and internal wave attenuation mechanisms, although low density generally reduces direct sound insulation [54].

A two-way analysis of variance (ANOVA) revealed that both coconut husk and Expanded Polystyrene (EPS) significantly influence the two main parameters—compressive strength and sound absorption coefficient of lightweight concrete—with a significance level of $p < 0.05$. Furthermore, the interaction between the two variables is also significant, indicating synergistic or antagonistic effects depending on the composition combination. This reinforces the importance of a multivariable approach in designing optimal composite materials. The multiple linear regression model developed to predict compressive strength and sound absorption capacity yielded determination coefficients (R^2) of 0.94 and 0.91, respectively. These values indicate that the model has a high level of fit in explaining the variation in experimental data. Response surface analysis revealed a consistent optimum performance point at a composition of approximately 1.0% coconut husk and 10–20% EPS, indicating the best balance between mechanical strength and acoustic performance.

ANOVA analysis was performed to assess the effect of mixed variables on acoustic performance. The F-statistic and p-value values indicate that fiber and EPS composition have a significant effect on the sound absorption coefficient at a 95% confidence level ($p < 0.05$), thus the regression model is declared significant. The validity of the RSM model was evaluated through residual analysis using a normal probability plot and a residual-versus-fitted plot. The distribution of residuals following a linear pattern and random dispersion against the predicted values indicated that the assumptions of normality and homoscedasticity were met, and there was no systematic bias, so the model was acceptable for prediction purposes [55].

A multi-response optimisation approach using the desirability function method was employed to simultaneously integrate the two target variables. The results indicate that the composition of 1.0%

coconut husk and 10% EPS is the optimal configuration, with predicted compressive strength of 28.5 MPa and sound absorption coefficient of 0.31. This composition is considered the most balanced in meeting functional and structural performance requirements while maintaining the characteristics of lightweight concrete suitable for non-structural and acoustic applications.

These results support the concept of multifunctional materials in eco-material engineering approaches [56]. The compromise between structural strength and acoustic performance is a critical aspect in modern concrete engineering, particularly for applications in partition walls, music studios, and office buildings [57]. The multi-response optimisation approach used is also aligned with the methods applied by [58], which emphasise the importance of quantifying trade-offs in composite materials.

The findings of this study indicate significant potential for the use of coconut husk and Expanded Polystyrene (EPS) as additives in environmentally friendly lightweight concrete. The modified concrete is highly suitable for application in non-structural elements, such as internal wall panels, acoustic ceilings, music studio partitions, and lightweight modular building components. However, there are several limitations that need to be considered. This study has not yet comprehensively evaluated the fire resistance and long-term durability of the modified concrete. Additionally, the durability of the concrete under humid environmental conditions and freeze-thaw cycles remains a concern that requires further investigation. Another challenge that may arise at the commercial application scale is the uniform distribution of fibres during mixing, especially in large volumes. Therefore, further research is recommended to integrate bio-material-based foamcrete technology and testing on a real-scale building. Furthermore, exploring the use of sustainable local alternative fibres, such as banana fibres or bamboo, as natural reinforcing materials is also highly worthwhile for further investigation. Further research is recommended to integrate bio-material-based foamcrete technology and testing at the building scale. Additionally, exploration of sustainable local alternative fibres such as banana fibres or bamboo as natural reinforcing materials is necessary.

4. Conclusion

This study demonstrates the potential of EPS–coir hybrid concrete for non-structural applications. However, claims of structural suitability require validation through 28-day strength and durability tests (moisture, fire, freeze–thaw). Through experimental approaches and statistical analysis, a comprehensive understanding of the role of each component in compressive strength and sound absorption capacity of concrete was obtained. This marks an important advancement in the development of multifunctional construction materials that support sustainability.The addition of coconut husk has proven effective in enhancing the compressive strength of lightweight concrete up to a certain limit. The most effective strengthening effect was achieved at a concentration of around 1%, where the fibres act as micro binders that reinforce the internal structure and slow down crack propagation. Conversely, the addition of Expanded Polystyrene (EPS) has a positive impact on the sound insulation capacity of concrete, particularly at medium frequencies, due to increased porosity and a hollow structure. However, an excessive increase in EPS concentration leads to a progressive decrease in compressive strength. The main limitations of this study include short curing duration (7 days) and lack of durability evaluation.

The optimal combination obtained in this study is within the range of 1% coconut husk and 10–20% EPS, which simultaneously provides compressive strength that still meets lightweight structural standards and significantly improved sound absorption coefficients. This composition reflects the ideal compromise between structural and acoustic functions in lightweight concrete.

This study successfully demonstrated a material design approach based on the utilisation of agricultural waste and plastic, in line with the principles of a circular economy. The use of coconut husk and EPS not only provides a technical solution but also offers a more sustainable material alternative for the construction industry. The modified concrete is highly suitable for application in non-structural building elements, such as wall panels, acoustic partitions, and lightweight modular components that require weight efficiency and sound control.

Declaration of AI and AI assisted technologies in the writing process

During the preparation of this work the authors used Grammarly in order to guarantee that the choices of words and the coherence as well as the cohesion are appropriate. After using this tool, the authors rewrite and edited the content as needed and take full responsibility for the content of the publication.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Recommendations

Further studies are highly recommended to explore long-term durability aspects, including moisture resistence, freeze-thaw cycles, and fire risks. Additional development efforts could focus on large-scale application and the use of alternative natural fibres from local sources, such as banana fibres or bamboo, which also have potential as reiforcing agents in environmetally friendy concrete.

References

[1] ROUTLEDGE HANDBOOK OF THE EXTRACTIVE INDUSTRIES AND SUSTAINABLE DEVELOPMENT. n.d.

[2] Istoan R, Manea LD, Plesa L, Tintisan ML. Increasing the sustainability of construction sector by developing new products based on biomass and renewable polymers - bibliometric analysis. IOP Conf Ser Mater Sci Eng 2022;1251:012005. https://doi.org/10.1088/1757-899x/1251/1/012005.

[3] Thao LQ, Cuong DD, Anh TTT, Luong TD. Profiling of Urban Noise Using Artificial Intelligence. Computer Systems Science and Engineering 2023;45:1309–21. https://doi.org/10.32604/csse.2023.031010.

[4] Amran M, Fediuk R, Murali G, Vatin N, Al-Fakih A. Sound-absorbing acoustic concretes: A review. Sustainability (Switzerland) 2021;13. https://doi.org/10.3390/su131910712.

[5] More FMDS, Subramanian SS. Impact of Fibres on the Mechanical and Durable Behaviour of Fibre-Reinforced Concrete. Buildings 2022;12. https://doi.org/10.3390/buildings12091436.

[6] Ali B, Hawreen A, Ben Kahla N, Talha Amir M, Azab M, Raza A. A critical review on the utilization of coir (coconut fiber) in cementitious materials. Constr Build Mater 2022;351. https://doi.org/10.1016/j.conbuildmat.2022.128957.

[7] Chiluka S. Coconut Fiber Reinforced Concrete by Complete Replacement of Sand with Over-Burden Soil. Journal of Ceramics and Concrete Sciences 2022;7:24–33. https://doi.org/10.46610/joccs.2022.v07i03.004.

[8] Martinelli FRB, Ribeiro FRC, Marvila MT, Monteiro SN, Filho F da CG, Azevedo ARG de. A Review of the Use of Coconut Fiber in Cement Composites. Polymers (Basel) 2023;15. https://doi.org/10.3390/polym15051309.

[9] Prasittisopin L, Termkhajornkit P, Kim YH. Review of concrete with expanded polystyrene (EPS): Performance and environmental aspects. J Clean Prod 2022;366. https://doi.org/10.1016/j.jclepro.2022.132919.

[10] Sabah Salahaldeen A, Ismail Al-Hadithi A. The Effect of Adding Expanded Polystyrene Beads (EPS) on the Hardened Properties of Concrete. vol. 12. 2022.

[11] Chun KS, Thangamuthu S, Yeng CM, Kiat OT. Effect of Coupling Agent on Properties of Composites Made from Styrofoam Waste and Coconut Shell. Journal of Physical Science 2022;33:1–15. https://doi.org/10.21315/jps2022.33.3.1.

[12] Naamandadin NA, Rosdi MS, Mustafa WA, Shahrol Aman MNS, Saidi SA. Mechanical behaviour on concrete of coconut coir fiber as additive. IOP Conf. Ser. Mater. Sci. Eng., vol. 932, IOP Publishing Ltd; 2020. https://doi.org/10.1088/1757-899X/932/1/012098.

[13] Bittner CM, Oettel V. Fiber Reinforced Concrete with Natural Plant Fibers—Investigations on the Application of Bamboo Fibers in Ultra-High Performance Concrete. Sustainability (Switzerland) 2022;14. https://doi.org/10.3390/su141912011.

[14] E Silva VGS, Sandes Filho CG, Angelin AF, Paiva AEM, Palma SSA, Gonçalves R, et al. Microstructural, mechanical, and acoustic analyses of concrete with EPS and silica fume. Revista IBRACON de Estruturas e Materiais 2025;18. https://doi.org/10.1590/S1983-41952025000800012.

[15] D SA, V.P VP, P VR, M AR, M D. Partial Replacement of Coarse Aggregate with EPS Beads. INTERANTIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT 2024;08:1–7. https://doi.org/10.55041/ijsrem39674.

[16] Han W, Yu H, Ma H. Experimental Study on Interface Strength Between Hardened Cement Paste-Aggregate. American Journal of Civil Engineering 2021;9:47. https://doi.org/10.11648/j.ajce.20210902.13.

[17] Thariq Resmaindra M, Arissaputra S, Teknologi Bandung I, Astra P. STUDI EKSPERIMENTAL PENGGUNAAN BUTIRAN EXPANDED POLYSTYRENE (EPS) SEBAGAI PENGGANTI PASIR PADA CAMPURAN BATA BETON. JCEBT 2024;8.

[18] Sun Y, Li C, You J, Bu C, Yu L, Yan Z, et al. An Investigation of the Properties of Expanded Polystyrene Concrete with Fibers Based on an Orthogonal Experimental Design. Materials 2022;15. https://doi.org/10.3390/ma15031228.

[19] Shendy M, Oluyemi M, Maftoon N, Salehian A. An Extensive Parametric Analysis and Optimization to Design Unidimensional Periodic Acoustic Metamaterials for Noise Attenuation. Applied Sciences (Switzerland) 2024;14. https://doi.org/10.3390/app14167272.

[20] Rodríguez-Díaz JM, Rivas-López MJ, Santos-Martín MT, Mariñas-Collado I. Optimal designs for a linear-model compositional response. Stochastic Environmental Research and Risk Assessment 2020;34:139–48. https://doi.org/10.1007/s00477-019-01755-2.

[21] Mkrtychev O V., Andreev MI. Numerical studies of strength of concrete cylinders for compression. Structural Mechanics of Engineering Constructions and Buildings 2019;15:433–7. https://doi.org/10.22363/1815-5235-2019-15-6-433-437.

[22] Mater YM, El Shahat AM, AbdelSalam SS. Experimental and numerical characterization of EPS using elastoplastic response in ABAQUS. Mater Today Proc 2023. https://doi.org/10.1016/j.matpr.2023.06.295.

[23] Gayki VD. Comparative Study of Properties of EPS with Regular Construction Materials. INTERANTIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT 2022;06. https://doi.org/10.55041/ijsrem13181.

[24] Acharjee D, Jyoti Basu D, Bandyopadhyay D. A numerical study on the through thickness shear behavior of EPS sandwich panels. Mater. Today Proc., vol. 62, Elsevier Ltd; 2022, p. 4379–85. https://doi.org/10.1016/j.matpr.2022.04.876.

[25] Obeid MH, Douzane O, Dutra LF, Promis G, Laidoudi B, Langlet T. Mechanical and thermal properties of an innovative bio based concrete. n.d.

[26] Schizas N V., Dahms HU, Kangtia P, Estronza AMG, Corgosinho PHC. Comment on Bang et al. Two New Species of the Genus Longipedia Claus, 1863 (Copepoda: Harpacticoida: Longipediidae) from Korea, with an Update and a Key to Species. Diversity 2021, 13, 590. Diversity (Basel) 2022;14. https://doi.org/10.3390/d14030200.

[27] Cavender-Bares J, Schneider FD, Santos MJ, Armstrong A, Carnaval A, Dahlin KM, et al. Integrating remote sensing with ecology and evolution to advance biodiversity conservation. Nat Ecol Evol 2022;6:506–19. https://doi.org/10.1038/s41559-022-01702-5.

[28] Kalauni K, Kumar D, Pawar SJ. Fabrication of green composites by waste coconut shells as partial replacement of coarse aggregates in concrete and determination of its acoustic behaviour. Indian Journal of Engineering and Materials Sciences 2023;30:112–21. https://doi.org/10.56042/ijems.v1.148842.

[29] Góra J, Piasta W. Test Results of the Modulus of Elasticity of Concretes with Various Coarse Aggregates and Standard Recommendations. Advances in Science and Technology Research Journal 2022;16:232–43. https://doi.org/10.12913/22998624/156583.
[30] Bazarbayev D, Aikenova A, Smagulova M, Nigmetova A. Qazaq Highway Science and Innovation DEVELOPMENT OF NOISE-INSULATING CONCRETE BASED ON RECYCLED INDUSTRIAL WASTE TO IMPROVE ACOUSTIC PROPERTIES OF BUILDING STRUCTURES n.d. https://doi.org/10.71031/Qazaq.
[31] Naidu GG, Babu NR, Ravikumar P. Strength Characteristics of Concrete by Partial Replacement of Coarse Aggregate with Coconut Shells & Cement with Glass Powder. IOP Conf Ser Mater Sci Eng 2021;1126:012060. https://doi.org/10.1088/1757-899x/1126/1/012060.
[32] Caixeta Silva TR, Silva de Aquino LA, Mesquita LC, Marques MG, de Azevedo ARG, Marvila MT. Innovative Cementitious Composites Produced with Corn Straw Fiber: Effect of the Alkaline Treatments. Applied Sciences (Switzerland) 2024;14. https://doi.org/10.3390/app142311117.
[33] Ahmed MI, Zafar A, Alturki R, Khan MI. Optimization and performance of expanded polystyrene concrete for sustainable infill wall construction using response surface methodology. Sci Rep 2025;15. https://doi.org/10.1038/s41598-025-07705-z.
[34] Van Deursen C, Suwan T, Laosuwan S, Wongmatar P, Kaewmoracharoen M, Suwan P. Development of Polymeric Binder from Expanded Polystyrene (EPS) Foam Waste as Construction Materials. IOP Conf. Ser. Earth Environ. Sci., vol. 1146, Institute of Physics; 2023. https://doi.org/10.1088/1755-1315/1146/1/012007.
[35] Machado BR, Silva LS, Amario M, Haddad AN, de Vargas AS, Stolz CM. Effect of curing methods on the long-term properties of concrete containing crystallizing additives. Next Materials 2025;8. https://doi.org/10.1016/j.nxmate.2025.100759.
[36] Amdani SA, Paikun P, Saepurrahman D, Susanto DA. Analysis of the compressive strength of concrete from brick wall waste as a concrete mixture n.d. https://doi.org/10.32832/astonjadro.v12i1.
[37] DEHDASHTI A, MALEKMOHAMADI A, GHAEINI G. Determining and Comparison of Sound Absorption Coefficients using Small Reverberation Chamber and Test Tube Methods. International Journal of Occupational Hygiene 2022. https://doi.org/10.18502/ijoh.v13i4.8426.
[38] Zhang Y, Li H, Abdelhady A, Du H. Laboratorial investigation on sound absorption property of porous concrete with different mixtures 2020;259.
[39] Ďuriš R, Labašová E. The design of an impedance tube and testing of sound absorption coefficient of selected materials. IOP Conf. Ser. Mater. Sci. Eng., vol. 1050, IOP Publishing Ltd; 2021. https://doi.org/10.1088/1757-899X/1050/1/012003.
[40] Othman IK, Mohd. Haniffah MohdR, Jamal MH, editors. Proceedings of the 5th International Conference on Water Resources (ICWR) – Volume 2. vol. 365. Singapore: Springer Nature Singapore; 2023. https://doi.org/10.1007/978-981-99-3577-2.
[41] Korondi PZ, Marchi M, Poloni C. Response surface methodology. Optimization Under Uncertainty with Applications to Aerospace Engineering, Springer International Publishing; 2021, p. 387–409. https://doi.org/10.1007/978-3-030-60166-9_12.
[42] He D, Zheng W, Chen Z, Qi Y, Zhang D, Li H. Influence of Paste Strength on the Strength of Expanded Polystyrene (EPS) Concrete with Different Densities. Polymers (Basel) 2022;14. https://doi.org/10.3390/polym14132529.
[43] Teixeira RS, Bufalino L, Denzin Tonoli GH, Dos Santos SF, Savastano Junior H. Coir fiber as reinforcement in cement-based materials. Advances in Bio-Based Fiber: Moving Towards a Green Society, Elsevier; 2021, p. 707–39. https://doi.org/10.1016/B978-0-12-824543-9.00008-6.
[44] Widianti A, Negara AAB, Elmino TS, Ramadhani L. UTILIZATION OF COIR FIBERS TO IMPROVE THE BEARING CAPACITY AND TENSILE STRENGTH OF EXPANSIVE

CLAY. International Journal of GEOMATE 2022;23:20–6. https://doi.org/10.21660/2022.95.16.
[45] Mailyan LR, Beskopylny AN, Meskhi B, Stel'makh SA, Shcherban EM, Ananova O. Optimization of composition and technological factors for the lightweight fiber-reinforced concrete production on a combined aggregate with an increased coefficient of structural quality. Applied Sciences (Switzerland) 2021;11. https://doi.org/10.3390/app11167284.
[46] Prasittisopin L, Termkhajornkit P, Kim YH. Review of concrete with expanded polystyrene (EPS): Performance and environmental aspects. J Clean Prod 2022;366. https://doi.org/10.1016/j.jclepro.2022.132919.
[47] Gahlot Pallavi S Randive PH. A REVIEW ON: THE EFFECT OF COIR FIBRE ON MECHANICAL PROPERTIES IN CONCRETE. vol. 5. 2020.
[48] Han J, Liao D, Li G, Lv Y, Cao K, Yang L, et al. Effect of high temperature on the performance of radiation-protected ultra-high performance concrete containing mixed fibers. Structural Concrete 2023;24:3191–207. https://doi.org/10.1002/suco.202200730.
[49] Zhang L, Huang M, Yang F, Zhang W. A novel hydrophilic modification method of EPS particles: Conception design and performances in concrete. Cem Concr Compos 2023;142. https://doi.org/10.1016/j.cemconcomp.2023.105199.
[50] Bhingare NH, Prakash S. An experimental and theoretical investigation of coconut coir material for sound absorption characteristics. Mater. Today Proc., vol. 43, Elsevier Ltd; 2020, p. 1545–51. https://doi.org/10.1016/j.matpr.2020.09.401.
[51] Ji J, Liu X, Tan S, Wang M, Ni W. Preparation and Performance Analysis of Foam-concrete Sound Absorbing Material Prepared Purely from Solid Wastes. Annales de Chimie: Science Des Materiaux 2019;43:37–42. https://doi.org/10.18280/acsm.430106.
[52] Fedyuk RS, Baranov A, Mugahed Amran YH. EFFECT OF POROUS STRUCTURE ON SOUND ABSORPTION OF CELLULAR CONCRETE. Construction Materials and Products 2020;3:5–18. https://doi.org/10.34031/2618-7183-2020-3-2-5-18.
[53] Ma'rifatul Maghfiroh A. Xxx xxxx. Journal of Energy, Mechanical, Material, and Manufacturing Engineering n.d.;x, No. xx.
[54] Kenchappa B, Shivakumar K. Development of lightweight micro-porous materials for acoustic applications. J Compos Mater 2022;56:4433–47. https://doi.org/10.1177/00219983221134151.
[55] Liu J, Xie H, Wang C. Optimization of compressive strength and sound absorption of foamed gypsum-cement composites based on response surface methodology. Case Studies in Construction Materials 2025;22. https://doi.org/10.1016/j.cscm.2025.e04566.
[56] Gribniak V. Material-oriented engineering for eco-optimized structures—a new design approach. Adv Mater Lett 2023;14:0–0. https://doi.org/10.5185/amlett.2023.011713.
[57] Fediuk R, Amran M, Vatin N, Vasilev Y, Lesovik V, Ozbakkaloglu T. Acoustic properties of innovative concretes: A review. Materials 2021;14:1–28. https://doi.org/10.3390/ma14020398.
[58] Sharma R, Pradhan MK, Jain P. Optimal selection of an AA8011 reinforced nano Si 3N 4composite using multi criteria decision-making method. Mater. Today Proc., vol. 56, Elsevier Ltd; 2022, p. 1399–405. https://doi.org/10.1016/j.matpr.2021.11.439.